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The Seventy-Ninth Meeting of the American Astronomical Society

By OLIVER JUSTIN LEE

This was a joint meeting with the Astronomical Society of the Pacific held in Pasadena, June 28-July 1, 1948.

The man, who coined the phrase The Great Open Spaces, could not possibly have imagined the added significance which the astronomers of the last three quarters of a century have given to the phrase. The traveler from the Atlantic seaboard to the Pacific moves by steps from the region of ordinary telescopes into the land of giants. Neglecting the strict chronology of the founding of these observatories, he comes upon the David Dunlap, the Perkins, Yerkes, McDonald, Lick, Mount Wilson, Victoria, and finally Palomar.

The hundreds of professional and amateur astronomers who journeyed across the mighty Rocky Mountains, as well as those who live on the borders of the Pacific, assembled as if for the climax of a pilgrimage, the scientific dedication of the Giant of Palomar. The fully attended sessions for papers at Pasadena and on Mount Wilson indicated wordlessly the instinctive desire of every person to earn for himself the right to share the thrill of seeing this man-made wonder of the world.

The Sessions

The number of persons, in excess of 150, whose names appear in the final notice from Secretary Huffer, was swelled to approximately 400 as the five sessions began and progressed. In this story no attempt will be made to summarize or even comment upon the 70 or more papers which were given. Most of them were highly technical, as usual. Abstracts are available and more complete reports will appear in the familiar journals and observatory contributions and annals. The subjects dealt with ranged from the detailed analysis of a single electromagnetic radiation to a model of the universe; from the intimate study of a single variable star to the incredible powers of modern calculators and observational instruments, which utilize the ingenious control of the flow of electrons.

To anyone who has followed the controversy, which followed Hale's announcement of the existence of the sun's general magnetic field several decades ago, the paper by Harold D. Babcock of Mount Wilson

seemed important and gratifying. He has measured this field from 1940 to 1947, has gotten annual means ranging from 5 to 60 gausses with an internal probable error of between 5 and 10 units, and concluded that the field exists and is variable.

The first session was opened by President Otto Struve. He introduced President DuBridge of the California Institute of Technology, who welcomed the members of the two societies and their guests to Pasadena. President Struve then asked speakers to reduce their times from 10 minutes to 8. At once Secretary Huffer and his interval timer got into action—warning bell at 7, and final bell at 8 minutes. The general adherence to this request made it possible for all sessions to close on time, and for all papers to be heard. A few of the speakers failed to close when the final signal came. From actual observation, the following formula can now be announced. The attention and interest of the audience decreases inversely as the cube of the excess time used by the speaker after the final bell has sounded. The patient listener tries to forgive the speaker who uses a soft but inadequate conversational tone when addressing an audience of hundreds of people. He cannot forgive those who regard questions and answers as private property, for they are not—by all that is fair, they belong to the audience.

Thanks to the faithfulness of the Secretary in using his interval timer, the last session on Friday afternoon was concluded a half hour early. This permitted a short, but unhurried, meeting of members of the International Astronomical Union, which in turn allowed plenty of time to prepare for the dinner that evening.

In this meeting, President Struve, who is also Chairman of the American Delegation which will attend the first post-war session of the I.A.U. in Zurich, Switzerland, in August, brought up some questions about which the delegation desired counsel and for action by the members who were present. In one or two cases specific directives were voted; for the others, decisions were left to the delegates when they meet in Zurich.

Demonstration at the Griffith Planetarium and Observatory

At the invitation of Director Dinsmore Alter and his staff, several hundred of us visited the Griffith Planetarium on Monday evening. This institution has a noble location some 2000 feet above metropolitan Los Angeles. It was in effect a demonstration of the kind of demonstrations which the public can enjoy almost at will. The handling of the lights at sunset, sunrise, and at night was excellent. The soft music was used with very distinctive discrimination and was most effective. The cultural impacts of such demonstrations are undoubtedly very great.

A special feature was the use for the first time of a zoom-lens to

give the effect of slowly approaching the full moon to within about 2000 miles. The picture filled a good part of the great dome. Probably there will in the future be introduced some of the magnificent pictures of details on the lunar surface made with the great telescopes, to complete the psychological experience of this trip to the moon. We were told that it is in the plans to use similar zoom-pictures of the sun, a globular cluster, and a galaxy such as the one in Andromeda. We all wished them good luck with these plans. One feature, which had never before been observed by this writer, was a swivel seat in each chair. This made it very easy to turn in any direction desired with practically no effort.

The Excursion to Mount Wilson

On Tuesday afternoon some 270 persons went by car or bus up the relatively new high-gear road for a short session, excellent movies of the making and mounting of the 200-inch reflector, dinner in relays at the hotel, and observation with the 60-inch and the 100-inch telescopes of the double star Alpha Herculis, Saturn, Jupiter, and the great globular cluster in Hercules. Even the indifferent seeing on that particular evening detracted not at all from the thrill of observing with these famous telescopes. The motion picture was a notably satisfying introduction to the actual viewing of the great 200-inch instrument on Thursday.

The views of distant mountains ever changing over the 20-mile road in a climb of a vertical mile, sunset, the coming out of stars on the dark blue vault of the sky, the popping out of lights into a veritable flood in the valley below, the long climb of iron stairs to the 100-inch telescope, and the brief glance into the vast open spaces with this veteran and its "little" 60-inch brother were a revelation to the untraveled plainsman, or his older fellow-astronomer who re-lives the drama of the experience.

The Society Dinner

Some two hundred persons dined with their friends on Wednesday evening at The Athenaeum Club on the campus of the Institute in Pasadena. Director Bowen of Mount Wilson and Palomar Observatories presided. He introduced the veterans, Dr. Aitken and Dr. Leuschner, then Mrs. William Wallace Campbell and Mrs. George Ellery Hale, the guests of honor. Following these presentations, Dr. Walter S. Adams spoke briefly for the hosts of the meeting, the two societies, and their friendly relationships. After remarking that to his knowledge this meeting had produced the highest concentration of astronomers per cubic centimeter of smog ever observed in this area, President Struve proceeded to report various items of interest to his astronomical family. He spoke of the serious existing deficiency in funds for publication, and was able to announce two substantial gifts to the Society from Mr. L. E. Peterson of Milwaukee, and Mr. Sullivan of In-

dianapolis. He urged the need of further such gifts from members and friends.

Professor Alice Farnsworth of Mount Holyoke College offered a verse-prose resolution of thanks to our hosts and to all who had contributed to our comfort and pleasure. As an example of this, knowing that some people would have trouble with over-heated engines up the mountain road to the Palomar Observatory, Dr. Bowen had ordered a service car to cruise up and down with tanks of water and to give such other service as anyone might need. Miss Farnsworth's resolution follows.

If I may presume to appear as official spokesman for some hundreds of persons who travel under the alphabetic designations of A.A.S and A.S.P.:

We came by bus, car, train, and plane
From Mass., Ohio, Washington, Maine.

We've had spirals and clusters, metallic-line stars,
And people who took us about in their cars.

Masses you measure and those you intuit
Problems to solve if you only can do it.

We've launched into space and watched Luna grow big
We've studied with Nassau, the red stars in Cyg.

We listened to tales of how fast is EDVAC
And wondered when comets will ever come back.

Television and yuccas and speeds supersonic
Lemonade and movies and nothing sardonic.

Saturn and cluster, the Ring in The Lyre
Till some must have wondered: "Will they ne'er tire?"

Our meals have been perfect; our quarters superb
Our pleasure and gratitude no one shall curb.

In plain and beautiful prose, we have seen an open cluster of some 400 people guided through space from peak to peak, smoothly and without serious disturbance from any massive galactic nucleus.

We wish to express deep appreciation for a wonderful meeting, including joys to come on the trip to Palomar Mountain, to

The California Institute of Technology, and its President, Dr. DuBridge,

The Carnegie Institution,

The Mount Wilson Observatory and the Palomar Observatory, and Dr. Bowen, director,

The Griffith Planetarium and Dr. Alter,

The Huntington Library,

Dr. Nicholson for his skillful, untiring, ubiquitous effort, and to many unnamed upon the staff of the observatories, the Athenaeum with its spacious hospitality, and the dormitories.

THE PALOMAR OBSERVATORY

The climax of our pilgrimage to see the Giant of Palomar has arrived. We had glided upward on a wide, smooth mountain road a dozen or so miles in length to the Observatory or had been helped by other colleagues or by Dr. Bowen's service car.

We enter the door of a spacious foyer and stand face to face with a life-size bronze bust of George Ellery Hale, whose vision, enthusiasm, and ability, persistently exercised through a quarter of a century, made this institution possible. This is the Hale Telescope. We go up a few steps to the main floor, and there is the telescope.

It just isn't so! It can't be!

The great size of the dome, the unconventional shape of the mounting and its immense size leave us speechless. It can't be so! Yet, there it is. The mounting is so large and massive that even the 200-inch aluminized mirror is dwarfed and all but lost in the assembly. The cylindrical observing cabinet at the prime focus is six feet in diameter but looks about half that large. The horseshoe-like upper polar bearing is 46 feet across and weighs about 155 tons. Only a few of the facts about this instrument can be given here. The whole weight of the moving parts is about 500 tons, one million pounds. It floats on oil films distributed through pads into which oil is forced continually under a pressure of between 400 and 500 pounds per square inch. "Friction is so slight that the telescope is moved with a 1/12-horsepower motor."

The observer sits on an ingeniously constructed chair in the cylinder-shaped cage at the prime focus of the great mirror (focal length 55.5 feet) and rides with the telescope. With the Cassegrain arrangement (equivalent focal length 267 feet) six auxiliary mirrors may be used. The Coudé assembly gives an equivalent focal length of about 500 feet and will be used entirely for spectrographic work. Quadruplet control dials enable the assistant to set right ascension, or hour angle, and declination on circles at the master control station under the north end of the polar axis. He presses a button and the motors move the telescope to the desired position with an accuracy of less than five seconds of arc. Repeater dials at observing stations for work at prime, Cassegrain, or Coudé focus enable the observer to check the assistant's settings at the control board. Observer and assistant communicate by telephone.

A short program was given in the dome, Director Bowen presiding. Dr. John A. Anderson described the making of the mirror and other optical parts, all done under his direction. Dr. Bruce H. Rule told about the mechanical problems encountered and how they had been solved. Dr. Walter Baade discussed the plans for the use of the telescope.

The rest of the day on the Mountain was spent informally. The guests wandered around at will, inspected the Schmidt Camera and other installations, and returned to Pasadena singly or in groups by

various routes, dining where convenient along the way. Conversation naturally centered around the great 200-inch.

The Program for the Hale Telescope

It takes no imagination at all to visualize the pressure to which the guiding spirits of this vast enterprise have been subjected by the public and especially by the newspapers and writers on science. Try to put yourself in their place. "Are you taking a photograph of Mars tonight?" asks one reporter. "Haven't you a photograph of the most distant galaxy ever observed?", says another. "My paper would like a glossy print of the first picture taken with the Hale Telescope," says a third. In his kindly way and with his marked probity, the Director simply says, in effect, that no photograph at all will be taken until we are all ready to take it.

As all working astronomers know, the difficulty encountered in photographing Mars or any other planet comes from bad seeing due to irregularities in the density along the air-path through our own atmosphere. Not even the 200-inch telescope can change that. The only way successful photographs of Mars and our other planetary neighbors have been made is to devote a telescope to the program and "sit it out" with the atmosphere for weeks and months, waiting for quiescent moments. This would be a stunt devoted to a gamble, if attempted with this telescope. This may not be done for years, perhaps never. With many fundamental tasks awaiting the doing, the Director and his councillors are much too wise and responsible to go "stunting."

These able and experienced men seem to reason in this fashion. Many direct trigonometric parallaxes of relatively nearby stars were needed to set up the grid of well-determined distances, upon which to base further probing into space by means of derived methods, such as spectrographic parallaxes and parallactic motions.

The remarkable results obtained from the use of the Period-Luminosity Law of Cepheid Variables have been checked and accepted gratefully by astronomers as the only solution of a problem which, up to its introduction, had been entirely intractable. Now the Hale Telescope will enable the observer to measure the individual Cepheids out to two or more times the distances so far explored and in roughly eight times as many stellar aggregations outside of our own galaxy. With this greater foundation of observed facts, a much more definitive system of absolute magnitudes of non-Cepheid giants will be established. These in turn will permit the extensions of present methods with a greater degree of confidence. Add to this the greater scope of counts of galaxies and their radial velocities now made possible, and it is easy to see that we will be slowly approaching the problem of the so-called expanding universe. Perhaps this great adventure may, in time, lead to a solution.

It has been felt that the famous North Polar Sequence of Stellar

Magnitudes is located too low in the sky for observatories in these latitudes. It is therefore proposed to take up another task with the 200-inch—the setting up of some few sequences in areas near the celestial equator. Because apparent magnitudes of stars enter directly into determinations of their absolute magnitudes or luminosities, it is clear that this job too is part and parcel of the larger ones described above.

Considerations such as these will govern the matters of the destinies of the Hale Telescope. Astronomers will understand why the emphasis in the programs has been placed where it is. The public will be disappointed because of the reportorial excesses which have multiplied themselves in the press for the last two decades or more. Even some astronomers, not in direct contact with the responsibilities of this magnificent adventure, have added to this misconception of its purposes by expressing hopes, perhaps, of quite immediate and spectacular results concerning the planets.

Of this we may all be sure. Every possible and impossible subject and angle has been thoroughly considered by the brilliant group of scientists and technicians who have lived with the Hale Telescope from the time when it was only a vague idea in their minds to the glorious day of its actual, accomplished physical reality.

From our hearts we can all say to them, "Happy congratulations, best wishes, and best of luck to you all."

Business Session

At the business session the following named persons were elected to membership in the American Astronomical Society.

Mr. Ernest C. Barkofsky, Box Navy-307, China Lake, California

Mr. William Burger, Warner & Swasey Company, E. 55th and Carnegie Ave., Cleveland, Ohio

Fr. James K. Connolly, S. J., Holy Cross College, Worcester 3, Massachusetts

Mr. Chester S. Cook, Harvard College Observatory, Cambridge 38, Massachusetts

Mr. Hal L. Cook, Warner & Swasey Company, E. 55th & Carnegie Ave., Cleveland, Ohio

Mr. Isadore Epstein, Princeton Observatory, Princeton, New Jersey

Miss E. Ruth Hedeman, Observatory, University of Michigan, Ann Arbor, Michigan

Dr. George H. Herbig, Students' Observatory, University of California, Berkeley 4, California

Mr. Walter Scott Houston, University of Cincinnati, Cincinnati 21, Ohio

Mr. Su-shu Huang, Yerkes Observatory, Williams Bay, Wisconsin

Mr. Ernest N. Jennison, Engineering Department, Warner & Swasey Company, Cleveland, Ohio

Mr. Franklin Edward Kameny, Harvard College Observatory, Cambridge 38, Massachusetts

Mr. Leslie W. Ketchum, 1014 Tumalo Trail, Madison 5, Wisconsin

Dr. Lincoln La Paz, Director, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico

Mr. William Liller, Harvard College Observatory, Cambridge 38, Massachusetts
Miss Jean Knox McDonald, Dominion Astrophysical Observatory, Victoria, B. C.
Mr. Frank S. McGary, 2016 Perrysville Avenue, Pittsburgh 14, Pennsylvania
Mr. R. D. McKnelly, 809 Chautauqua, Norman, Oklahoma
Mr. Albert G. Mowbray, 980 East Washington Street, Pasadena, California
Mr. William W. Olsen, 1447 Bellford Avenue, Pasadena 7, California
Mr. Robert M. Page, Observatory, University of Michigan, Ann Arbor, Michigan
Mr. Paul E. Roques, Griffith Observatory, P. O. Box 9787, Los Feliz Station, Los Angeles 27, California
Dr. John A. Russel, Department of Astronomy, University of Southern California, Los Angeles 7, California
Mr. Allan R. Sandage, University of Illinois Observatory, Urbana, Illinois
Mr. Albert V. Shatzel, 820 East 52nd Street, Chicago 15, Illinois
Mr. Arne Slettebak, Yerkes Observatory, Williams Bay, Wisconsin
Mr. Philip C. Stanger, Mathematics Department, Oklahoma A. & M. College, Stillwater, Oklahoma
Dr. J. S. Supernaw, Tenney Building, Madison, Wisconsin
Mr. Charles Stillwell, Warner & Swasey Company, Cleveland, Ohio
Mr. Conrad D. Swanson, Box 10, N.O.T.S., China Lake, California
Mr. Marvin L. White, Yerkes Observatory, Williams Bay, Wisconsin
Mr. Uco Van Wijk, Harvard College Observatory, Cambridge 38, Massachusetts
Mr. Marshall H. Wrubel, Yerkes Observatory, Williams Bay, Wisconsin
Mr. Paul E. Wylie, 2319 St. George Street, Los Angeles 27, California

The secretary stated that six members of the Society had died in the course of the year just closed. The audience stood as a mark of respect as their names were read. They were

Roy W. Delaplaine	William Henry
Henri Deslandres	Julius F. Stone
Arthur M. Harding	Arthur B. Turner

It was also decided that the eightieth meeting of the Society shall be held at Yale University, New Haven, Connecticut, December 28-31, 1948. The eighty-first meeting in the summer of 1949, the exact dates not yet determined, will probably take place in Ottawa, Canada.

The Distribution of the Longitudes of Periastron of Spectroscopic Binaries

By OTTO STRUVE

The great majority of close binary stars are so far away that they cannot be resolved even with the most powerful telescopes in existence. Such binaries can be investigated with the help of a spectrograph which enables us to measure the projection upon the line of sight of the velocity of one, or of both, stellar components at any point in their

respective orbits. As was shown many years ago by Lehmann-Filhés it is possible to derive from the measured radial velocities of a spectroscopic binary the average orbital velocity, K, of each star, the shape of the orbit as measured by its eccentricity, e, and the orientation of the long axis of the orbit with respect to the line of intersection between the plane of the orbit and a plane at right angles to the line of sight. This quantity is designated by ω and is called the longitude of the periastron or of the line of apsides. If the elliptical orbit is elongated in a direction which coincides with the line of sight, ω is either 90° or 270° depending upon whether the star passes through the periastron when it is at the most distant point of its orbit, or when it is at the nearest point of its orbit. When the long axis of the double star's orbit is at right angles to the line of sight, ω is either 0° or 180° depending upon whether the star is moving away from us as it passes through periastron or is approaching us.

Ever since astronomers began to investigate the properties of double stars they have been making statistical studies of the distribution of the different elements which describe the orbits. For example, it was found long ago that the eccentricities are very small when the periods are short, and that statistically the orbits become more and more elongated as we consider systems of longer and longer period. One of the most unexpected results of these studies was a decided tendency of the angle ω to be more often between the values of 0° and 90° than among the other quadrants of the circle. If, as was reasonable to expect, the orbits of the binaries are distributed at random in space we should have expected that except for minor random fluctuations the distribution of ω would be approximately the same in all four quadrants. There has been a great deal of discussion during the past forty years regarding the reality of the uneven distribution of the values of ω and of its possible physical significance, and the opinions of the astronomers have been divided: many were inclined to regard the unevenness of distribution as a result of pure chance; others accepted the published data as an expression of a real phenomenon in nature and attempted to find an explanation in terms of the known properties of binary systems.

The last compilation of data showing the distribution of ω was made by R. G. Aitken[1] in 1935. Since then a large number of new orbits have been determined. In view of the interest attached to this problem,[2] I have collected all available material and presented the results in Table 1, separately for the eclipsing and the non-eclipsing spectroscopic binaries. Figure 1 shows the smoothed totals, in groups of four, for all eccentricities.

The first column of the Table gives those systems which have circular orbits or for which the observations were so uncertain that e is practically indeterminate. This accounts for 42 systems which have no eclipses and 60 systems which do have them. The large number of

TABLE 1

DISTRIBUTION OF

*—NON-ECLIPSING SYSTEMS; o—ECLIPSING SYSTEMS

e	$\omega°$ Indeterminate *	Indeterminate o	1-15 *	1-15 o	15-30 *	15-30 o	30-45 *	30-45 o	45-60 *	45-60 o	60-75 *	60-75 o	75-90 *	75-90 o	90-105 *	90-105 o	105-120 *	105-120 o	120-135 *	120-135 o	135-150 *	135-150 o	150-165 *	150-165 o	165-180 *	165-180 o	180-195 *	180-195 o
0.00	42	60																										
0.00-0.03			4	2	2	0	3	3	3	0	1	0	0	0	4	0	4	0	3	1	2	0	2	0	1	0	4	0
0.03-0.06			3	1	4	0	1	2	3	0	2	2	3	1	5	0	0	2	4	0	1	1	2	1	1	0	2	0
0.06-0.09			2	0	2	0	0	0	2	1	2	1	3	0	1	0	1	0	1	0	0	0	1	1	1	1	1	1
0.09-0.12			3	0	1	0	3	0	2	0	1	0	0	0	3	1	0	1	1	0	0	0	0	0	2	0	2	0
0.12-0.20			1	2	0	1	1	1	2	0	0	0	0	1	3	3	1	0	1	1	2	0	1	1	3	0	1	0
0.20-0.30			5	3	2	2	2	1	2	0	3	1	2	0	5	0	2	3	1	0	3	0	1	0	1	0	2	0
0.30-0.50			5	0	3	3	2	1	4	0	3	0	3	0	4	0	2	0	5	0	2	0	2	0	1	0	4	0
0.50-0.75			2	1	2	0	1	0	2	0	2	0	2	0	2	0	2	0	0	0	1	0	0	0	1	0	3	1
0.75-1.00			0	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			25	9	17	6	14	8	21	1	15	4	14	2	27	4	12	6	16	2	11	1	9	3	11	1	19	2

TABLE 1 (*continued*)

DISTRIBUTION OF

*—NON-ECLIPSING SYSTEMS; o—ECLIPSING SYSTEMS

195-210		210-225		225-240		240-255		255-270		270-285		285-300		300-315		315-330		330-345		345-360		Totals	
*	o	*	o	*	o	*	o	*	o	*	o	*	o	*	o	*	o	*	o	*	o	*	o
0	0	2	0	1	0	1	0	1	0	1	0	1	0	2	1	0	1	3	0	3	1	48	9
1	0	2	1	1	0	0	0	2	2	1	0	1	0	1	0	0	0	2	2	1	1	43	16
1	0	2	0	0	0	1	0	0	0	1	1	1	0	1	0	0	2	1	0	0	0	25	8
1	1	0	1	0	0	0	1	0	0	5	0	3	0	1	1	0	0	1	1	0	0	29	7
3	1	1	0	3	0	0	0	2	1	4	0	0	0	0	0	2	0	0	2	2	0	33	14
2	0	3	0	1	1	3	0	1	0	0	0	3	0	2	0	0	0	2	2	0	0	48	13
1	0	2	0	1	0	0	0	5	1	3	0	1	0	2	2	3	0	1	1	2	1	61	9
1	0	4	0	0	0	1	0	3	0	0	0	1	0	1	0	1	0	5	0	5	0	42	2
1	0	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	1	0	1	0	12	0
11	2	16	2	8	1	7	1	14	4	17	1	11	0	10	4	6	3	16	8	14	3	341	78

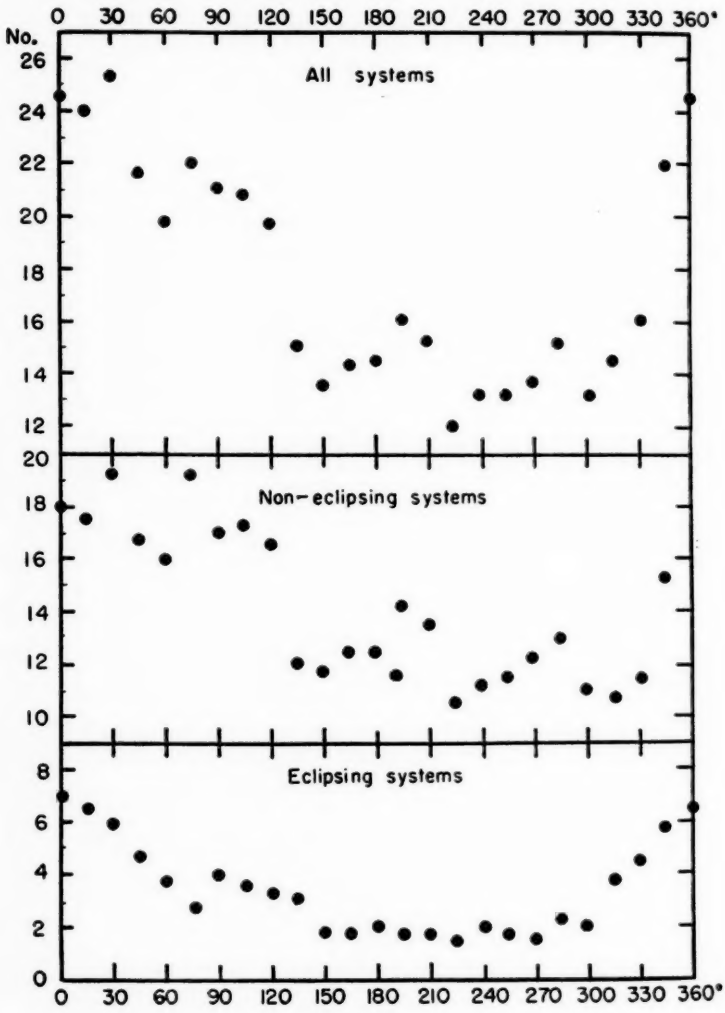


FIGURE 1

SMOOTHED FREQUENCY DISTRIBUTION OF ω

eclipsing systems in this group is caused partly by observational selection which favors the discovery of eclipses in systems of short period and partly by observational causes: most of these 60 systems were observed with small dispersion because they are very faint. It is probable that even among those systems for which the observers computed

eccentricities, having $0.00 < e \leq 0.03$, many are in reality indeterminate.

The Table excludes all Cepheid variables, β Cephei stars and other intrinsic variables which are known not to be real binaries. It includes a number of other doubtful stars (ϕ Persei, etc.) which may or may not be binaries. There is as yet no reliable criterion for excluding them. As far as we know these remaining doubtful cases are few in number and show no systematic tendency to cluster at values of ω in the first quadrant.

The total number of entries in the table with listed values of ω is 419 as against Aitken's total of 275. In those systems which show the spectra of both components I have used the one that is stronger in the spectrum. Thus, the data refer almost uniformly to the more massive components.

The general relation between frequency and ω is unmistakable: there is a marked maximum near $\omega = 15°$ and a broad minimum near $\omega = 225°$. The character of this distribution is new, and the maximum which was thought by the earliest workers to occur near $\omega = 90°$ and by Aitken in 1935 near $\omega = 45°$ is now even closer to 0°. However, it should be emphasized that the essential feature of the distribution is the concentration of systems with ω in the first quadrant. An attempt to explain this distribution was presented in an earlier paper.[2]

REFERENCES

[1] The Binary Stars, Second Edition, McGraw Hill Book Co., 1935, p. 214.
[2] *Pub. A.S.P.*, **60**, 160, 1948.

YERKES OBSERVATORY, JUNE 24, 1948.

On Shadow Bands at Total Eclipses of the Sun

BY E. GAVIOLA

ABSTRACT

Photographs of shadow bands obtained by star light are shown.

At total eclipses the source is the solar crescent. It is shown how the crescent produces the observed bands.

INTRODUCTION

Many total-eclipse observers have witnessed and described the appearance—within a few minutes (up to 10) before and after totality—of shadow bands or flying shadows. The facts about them appear to be as follows:

1. The bands are approximately parallel to the tangent at the center of the solar crescent. Angles of the order of 16 degrees have nevertheless been reported between radius of the moon's shadow and the direction of bands movement.

2. The "wavelengths" reported vary from 66 to 7 cm. The shadow bands have shortest wavelengths and best contrast immediately before and after totality. Wavelength increases and contrast decreases with growing width of the solar crescent.

3. The bands move at right angles to their orientation, either towards or away from the moon's shadow. Their transversal velocities vary from zero to amounts of the order of gentle wind velocities. Shorter wavelengths have generally greater speeds.

4. If shadow bands are seen before and after totality they need not be parallel to each other. At the central line of totality they sometimes are.

Essentially correct, although incomplete, explanations of the phenomenon have been given by many authors (*e.g.*, R. W. Wood, "Physical Optics," 3rd Edition, page 91, 1934) connecting the flying shadows with refraction in the atmosphere. Nevertheless publications continue to appear attributing the effect to "diffraction, or at least some interference phenomenon. . ."[1] A detailed explanation may therefore not be superfluous.

Shadow Bands by Starlight

Shadow bands whose characteristics resemble the ones described are familiar to observing astronomers: they are seen when a bright star is in the field and the eyepiece is removed, replacing it with the naked eye. Although easy to see, they are difficult to photograph. A powerful telescope is necessary.

Figure 1 shows a few shadow bands photographed by starlight. They were obtained with the 60-inch reflector of the Córdoba Astrophysical Station at Bosque Alegre, placing a 12 and a 7.5 cm focus camera some 30 cm inside the Cassegrain focal plane. The equivalent focal distance of the telescope—3150 cm—is not essential; the Newtonian focus could just as well have been used. An auxiliary camera of short focal distance is essential as exposure times have to be small on account of the sometimes rapid transversal displacements of the flying shadows.

The pictures show the shadows on the main mirror of the reflector. The central obstruction and the cross lines are the shadows of the secondary mirrors and of their supports.

Picture 1 was taken with light of β Centauri using the 12 cm focus camera and an exposure time of 1/10 second. Two shadow band systems can be seen, having both the same wavelength, $L = 7$ cm, but different orientations: S22°W and S65°W. The definition is not very good, perhaps on account of the relatively long exposure. With a shorter-focus camera and brighter stars, shorter exposure times could be used.

[1] R. L. Feldman, Popular Astronomy, Vol. **48**, pages 183 and 352 (1940); *ibid.*, Vol. **56**, page 24 (January, 1948). See also S. A. Mitchell, "Eclipses of the Sun," *Handbuch d. Astrophysik*, B. **4**, page 353 (1929).

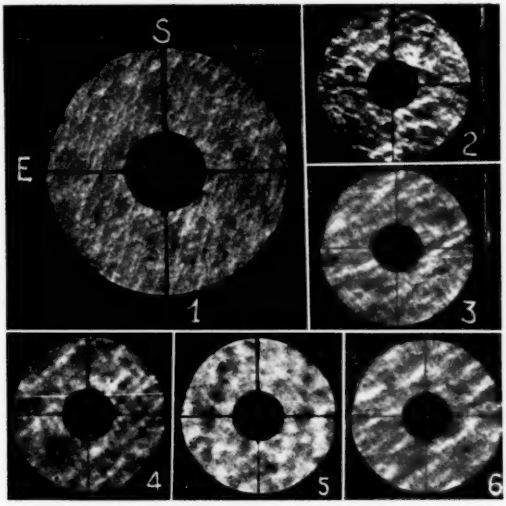


FIGURE 1

SHADOW BANDS BY STAR LIGHT. 10X ENLARGEMENTS

1—β Cent, 1/10 sec, Sept. 6, 47, 0.30 UT; 2 systems: L = 7 cm inclined 43° between them;

2—Sirius, 1/50 sec, Oct. 3, 47, 6.20 UT; 2 systems: L = 9 cm and L = 21 cm.

3—Sirius, 1/50 sec, Oct. 3, 47, 5.45 UT; 3 systems: 1 L = 7 cm and 2 ill defined ones (L = 18 cm?)

4—Sirius, 1/10 sec, Oct. 4, 47, 6 UT; 3 systems: L = 7 cm, L = 30 cm, and L = 22 cm.

5—Canopus, 1/25 sec, Sept. 5, 47, 6 UT; L = 6 cm, L = 90 cm and a third ill defined system.

6—Sirius, 1/50 sec, Oct. 3, 47, 5.40 UT; L = 6 cm and L = 20 cm irregular.

Picture 2 is a 1/50 of a second exposure of Sirius showing two band systems strongly perturbed by perhaps other superimposed waves: one has L = 9 cm and is oriented S64°E; the other L = 21 cm, S69°W. Contrast is strong, showing powerful refraction.

In picture 3, taken on the same night as the preceding one, up to three band systems can be individualized, although two of them are irregular. The first one—S50°E, L = 7 cm—is rather neat; the other two are nearly normal to the first one.

Picture 4 is a longer exposure—1/10 second—and the wave systems appear somewhat diffuse, due, probably, to transversal displacement. Three systems can nevertheless be recognized: L = 7 cm, S37°E: L = 30 cm, S50°W, and L = 22 cm, S47°W.

Picture 5—1/25 second with light of Canopus—shows the bands formed by somewhat round spots of light and shadow, indicating

strong perturbations. The short wavelength system —L = 6 cm, S45°E—is still to be seen; a second system of long wavelength—L = 90 cm, S11°W—is well shown; a third band running WSW to ENE appears at the lower part of the picture; its wavelength may be longer than the part of the diameter of the mirror still available (130 cm).

Picture 6 shows the by now familiar shortwave system—L = 6 cm, S40°E—and an irregular one almost normal to the first—L = 20 cm, S60°W—with regions of strong contrast. The bands appear interrupted by perturbations.

As no cinematographic record was taken, the transversal velocities of the wave-system shown cannot be stated. Only an upper limit can be set: velocities are smaller than half the wavelength divided by the exposure time.

Other systems may be present but will not show if their wavelengths and transversal speeds do not fulfill that condition. The shadow bands photographed may therefore be a selection excluding smaller wavelengths and larger velocities.

Shadows of wave systems are rather unstable. Pictures 2, 3, and 6 were taken the same night 35 and 5 minutes apart. The change from the first to the second is well marked; the second and third resemble each other somewhat, but this does not mean that the structure has lasted nearly undisturbed for 5 minutes. Visual observation and the study of traces of images shot across a plate[2] show that a particular configuration lasts on a "poor night" not more than a few hundredths of a second. Most of the time only an irregular "boiling" of the light can be observed. The pictures shown have been selected among many more taken because they show some regular band structure. On nights of good seeing wave systems show more stability.

Shadow Bands by Solar Crescent Light

The shadow bands shown by star light are the result of refraction at the inversion layer wave systems above the observer. There may be up to about 7, each at a particular height. Inversion layers are familiar to meteorologists and to aviators. Their waves produce discomfort among air line passengers. As the waves are produced by the relative displacement of one air mass above another, their crests are normal to the relative wind. This is why they move transversally. Their velocities and wavelengths are related to the wind speeds.

If the light source is not a bright point but a bright line, a selection will take place among the different wave systems present.

Two cases may be distinguished.

1. *Narrow straight source of limited length* (solar crescent seconds before or after totality). If we call *d* the length of the source projected

[2] Paper on "Seeing, Fine-Structure of Stellar Images, and Inversion Layer Spectra" appearing elsewhere.

at the inversion layer, α the angle of it with the waves and L, as before, the wavelength, a band system will produce a detectable shadow only if

$$L > d \sin \alpha \tag{1}$$

The projected length d depends on the height H of the inversion layer, on the zenith distance z of the light source and on the angle β of the tangent at the center of the crescent with the vertical plane thus:

$$d = \theta \times H\,(1 - \cos\beta + \cos\beta/\cos z)/3438 \cos z \tag{2}$$

where θ is the angular length of the light source in minutes of arc and H is to be taken in the same units as d.

Systems of short wavelength L will show only if nearly parallel to the crescent and preferably if they belong to low inversion layers. For longer wavelengths the angles and the heights can be larger.

2. *Solar crescent minutes before or after totality.* The source is not straight and has a perceptible width. Conditions appear now at first sight (see Figure 2) less favorable for projecting detectable shadows. The opposite is nevertheless statistically true.

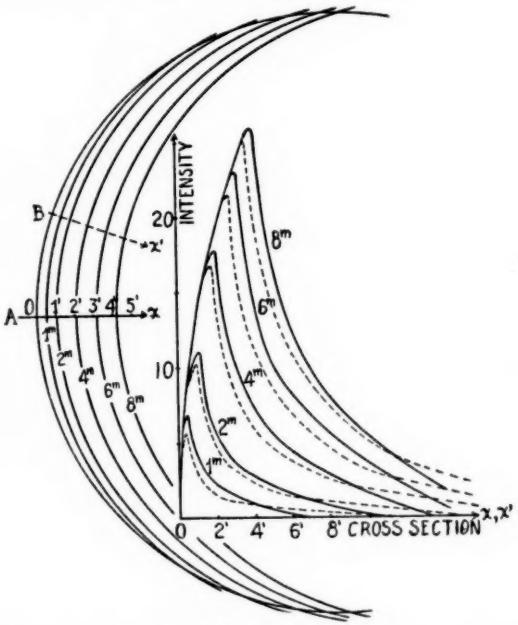


FIGURE 2
INTEGRATED TRANSVERSAL INTENSITY DISTRIBUTION OF SOLAR CRESCENTS FOR 1, 2, 4, 6, AND 8 MINUTES FROM TOTALITY

The crescent is curved and has a considerable length. The integrated transversal intensity distribution has nevertheless a rather narrow maximum and this sharp maximum is not very particular regarding the direction in which one takes the cross section (within limits).

In Figure 2 the solar disc has been drawn with radius 1 and the receding moon with radius 1.04 for the instants corresponding to 1, 2, 4, 6, and 8 time-minutes after third contact (or, inverting the order, before second contact). The eclipse is observed from the central line of the totality zone.

In order to know the optical effect of a crescent on an inversion layer wave-system parallel to the (projected) tangent at its center, it is convenient to integrate the light distribution along the central cross section. The integration can be done graphically taking equal intervals Δx along the A—x axis and adding the surface elements of the crescent that fall within the ordinates corresponding to the interval. The intensity distribution curves of Figure 2 (full lines) are thus obtained.

As can be seen, there is a rather sharp maximum present even when the crescent is already rather wide. This maximum rests on a widening base. The maxima will project shadows of favorably oriented waves upon a diffuse background of light produced by the bases. The ratio of the narrow tops to the wide bases will determine the contrast.

The width of the top part grows slowly with time. Even 2 minutes after totality the top is only a little more than 1 minute of arc wide. A wave-system of $L = 20$ cm at $H = 500$ m will show, if favorably oriented, in spite of the fact that the basis of the 2 minutes curve is much wider. This will produce only a uniform illumination reducing the contrast.

As time distance from totality increases, contrast will progressively decrease. Shadow bands are easier to see than to photograph because eyes are more sensitive than plates for detecting small contrast.

As the number of wave systems available at a particular moment above the head of a given observer is small, the probability of detecting one would be nearly zero if only bands parallel to the tangent at the central part of the crescent would project visible shadows. But according to reports of total eclipse observers the probability of seeing any bands is not small. This is because waves need not be parallel to the central part of the crescent in order to be seen.

In fact, if we repeat the integration of intensity distribution along a new axis $B - x'$ inclined 20° to the former one we obtain the results drawn by dotted lines. The bases of the new curves have grown, as could be expected. But the tops have become narrower than before. This means that bands of wavelengths smaller than could be detected before will now be visible but with diminished contrast.

Bands not parallel to the tangent at the center of the crescent have

been reported.[3] They should be common among the observed ones if orientations were determined with care.

The transversal speeds reported are generally smaller than common wind velocities. This is, no doubt, a result of optical selection: bands of wavelengths of the order of decimeters can not be followed by the eye if the transversal speeds are larger than a few meters per second. Only the stationary or slow moving ones can be distinctly seen.

Wavelengths, Heights of Inversion Layers, and Contrast

The contrast with which a given inversion layer wave system could be observed when illuminated by a solar crescent depends on many variables. If one wished to predict it, one would need: 1. To know the wavelength, the height, the orientation, and the optical power of the wave system; 2. To know the width, the zenith distance, and the position angle of the crescent; 3. To draw the integrated transversal intensity distribution curve of the crescent corresponding to the normal to the direction of the waves projected upon the plane of the crescent; 4. To calculate the angular width of the waves

$$\theta = 3438\, L \cos z/H\, (1 - \cos\beta + \cos\beta/\cos z) \qquad (3)$$

(β is the angle of the plane containing the normal to the waves with the vertical plane); 5. To draw upon the integrated transversal intensity curve two ordinates separated a convenient fraction of the calculated width in such a way that a maximum intensity area is enclosed; to measure the ratio of the enclosed to the excluded area; 6. To repeat the former operation varying the fraction of the angular width chosen until the contrast factor determined by the choice, multiplied by the ratio measured in 5 is a maximum; 7. The number so obtained and the optical power of the waves permit the calculation of contrast.

Without going into so many operations it is interesting to consider minimum values of L and maximum heights under simplified conditions. If we set $z = 0$ (3) reduces to $\theta = 3438L/H$. If we define as "effective width" the one that encloses one-third of the surface of the normal transversal distribution curves we obtain the values given in the following table.

Shortest Observable Wavelength

Minutes of time	Effective width	H = 100	500	1000	5000 meters
1	0'9	2.6	13	26	131 cm
2	1'2	3.5	17.5	35	175 cm
4	1'5	4.4	22	44	218 cm
6	2'0	5.8	29	58	291 cm
8	2'3	6.7	33	67	334 cm

According to this, wavelengths of the order of 10 cm observed 2 minutes before or after totality belong to inversion layers no higher than about 300 meters above the observer's head.

[3] E. S. Holden, *Mem. Nat. Ac. of Sc.*, Vol. II, p. 102 (1883).

Shadow Bands by Planetary Light

The larger planets have diameters comparable to the effective width of the solar crescent one minute before or after totality. Comparing cinematographic series of shadow bands obtained by starlight with analogous series by planet light the approximate heights of certain characteristic inversion layer wave systems should be obtained.

I wish to thank Dr. Ricardo Platzeck also in this place for his valuable assistance and for having read this paper in manuscript.

Córdoba Observatory, Argentina, March, 1948.

Terrestrial Cycles

By H. H. CLAYTON*

Summary

(Prepared by Miss Frances Clayton)

The sunspot period is a period of variable length and is not commensurate with the annual period. When sunspots are increasing new eruptions are occurring in the solar atmosphere bringing new matter from the interior of the sun, whereas when spots are diminishing this process is reversed and heated clouds are diminishing in number. From this point of view the rate of increase of sunspots is more important in modifying solar influence than is the absolute number of spots. Outside the tropics over the continents the relation is reversed between summer and winter.

A ten-year cycle consisting of three cycles of about 3⅓ years has been found. In twenty-year intervals there are six oscillations of pressure averaging about 3.32 years. 20-year intervals show a more exact resemblance than do 10-year intervals.

It is generally accepted that certain electrical and magnetic conditions of the earth and its atmosphere are closely correlated with the eleven-year sunspot period. I have found also that when the pressure of the atmosphere is averaged in moving means of five years in the tropics the results show a fairly close relation to the eleven-year sunspot period. Outside the tropics over the continents the relation is reversed between summer and winter.

Very few terrestrial cycles, however, seem to fit into the sunspot period. This fact has been a puzzle for many years. Recently after considerable study of the subject, I have decided that the reason lies in the fact that the eleven-year sunspot period is not commensurate

*The author of this paper died on October 26, 1946. The manuscript was sent to us by his daughter, Miss Frances Clayton. He was the author of the book "Solar Relations to Weather."

with the annual period of the earth. This annual period with its successive seasons of spring, summer, autumn, and winter is the dominating factor in earthly affairs. Increase of solar activity in winter could produce no influence on plant, insect, fish, or on any manifestation of animal life which lies dormant in winter. The sunspot period is a period of variable length and is not commensurate with the annual period. There are two variations in sunspot activity, however, which come very close to some multiple of the annual period. One of these is a period of about eight years and the other a period of about ten years. Analysis of the sunspot numbers into periods of different lengths has been made by a number of different research workers. The results are given in Table 5.

TABLE 5

LENGTH OF SUNSPOT PERIODS IN YEARS FOUND BY VARIOUS RESEARCH WORKERS

A. Schuster	(1906)	..	4.8	...	...	...	8.4	....	11.13	13.5	....	....
K. Stumpff	(1928)	..	...	5.6	7.3	...	8.8	10.0	11.13	12.9	14.3	20.5
D. Alter	(1928)	..	...	...	7.6	8.1	8.7	10.0	11.37	....	14.0	21.0
A. E. Douglass	(1936)	..	...	...	...	...	8.5	10.0	11.4	13.5	14.3	....
H. H. Clayton	(1938)	..	...	5.6	...	8.1	8.9	9.9	11.17	11.9	14.9	19.9

Four out of five of these researches show a period of almost exactly ten years. This period of ten years appears to be the dominant cycle outside of the annual and diurnal periods.

This fact was brought out strongly by the group of investigators brought together by Copley Amory. In July, 1931, a group of scientists and business men assembled at his camp on Matamek River near Anticosti, Labrador, the object of the meeting being "to advance human prosperity through conclusions drawn from the study of biological cycles." The meeting was known as the "Canadian Biological Conference." The following is quoted from an account of its proceedings which appeared in the *New York Times* of August 14, 1931.

"In the plains of Edmonton, according to Dr. Rowan, a cycle of almost ten years is evident in grouse, other migrating birds, and rabbits, and also their enemies, such as coyote, lynx, red fox, and other fur bearers. Farther north the voluminous records of the Hudson Bay Company have given Mr. Elton abundant data which show a cycle of 9.7 years in hares, muskrats, grouse, lynx, red fox, marten, wolf, mink, and goshawks."

Still another type of evidence of the ten-year cycle was contributed by Dr. Huntington. His measurements of the annual rings of growth in the giant Sequoias of California showed variations in the rate of growth recurring in about ten years.

Thus once in ten years or a little less, something seems to happen which causes an increase and then a decrease in the vital activities of both animals and plants all over North America, from the borders of Alaska to the Maritime Province and Northern United States, and also in adjacent seas.

To complete the picture, Aurel Comises, a Roumanian graduate of the Schemnitz Forestry School of Hungary, presented evidence of a ten-year cycle of disease in the rabbits of Europe.

Since the Canadian Biological conference, Mr. Amory has promoted the organization of the "Foundation for the Study of Cycles" of which he remains chairman and to which many notable men of the United States, Canada, and Great Britain have added their names as directors or consultants. Edward R. Dewey has been appointed director and has actively collected and reprinted the many scattered investigations on cycles.

A surprising amount of evidence has accumulated of the existence of a cycle of about ten years, or a little less, in growth of trees, the increase and decrease of animal life, insects, of fish and of birds. A ten-year cycle consisting of three cycles of about 3⅓ years has also been found in tree growth, in rainfall, and in barometeric pressure, in the price of industrial securities, in pig iron production and price, and in other human activities.

Unfortunately, most of the research workers have adopted the generally accepted view that every cycle should be a mathematical cycle of constant length and amplitude and a difference of opinion has arisen as to whether the 3⅓-year cycle is a cycle of about 40 months or a little less, or a cycle of 41 months. The evidence, however, favors the view that this cycle like most of the solar and meteorological cycles is of varying length and amplitude, and not a cycle constant in length or a combination of such cycles.

Graphs have been made which show that since about 1945 the abundance of hares and lynxes has fluctuated in periods of about ten years with maxima near the middle of each decade from 1845 to 1925 and minima on or near the beginning of each decade from 1850 to 1930.

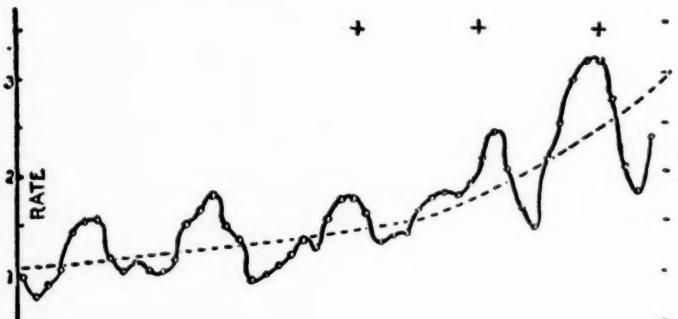


FIGURE 1

These two cycles are closely related because the lynxes are dependent on the snowshoe rabbit for food.

Figure 1 shows a smoothed plot of the number of fish taken from the Restigouche River, Canada. It was prepared by Earl B. Phelps, of Columbia University and D. L. Belding of Boston University School of Medicine for the years 1880 to 1929. The general trend upward of the fish population is shown by the broken line while the variation from year to year is shown by the full line. This line shows a maximum in the number of fish near the middle of each decade from 1885 to 1925 and minima near the beginning of each decade from 1880 to 1920. The plus signs show maxima in the yearly values of solar radiation which occurred also near the middle of the decades from 1905 to 1925.

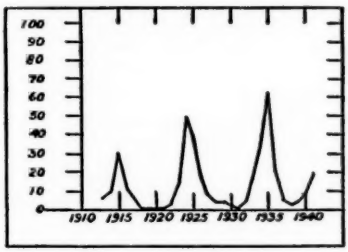


FIGURE 2

Figure 2 shows a plot of an index of abundance of tent caterpillars in New Jersey. It was made by Thomas J. Headlee, State Entomologist, for the years 1913 to 1941. This plot also shows maxima of abundance near the middle of each decade from 1915 to 1935 and minima near the beginning. The report of the Matamek Congress states that a similar cycle was found in the abundance of goshawks, but a plot of this cycle is not available.

A. E. Douglass, Director Emeritus of Steward Observatory, who has made a life study of the growth of trees in the southwestern United States and in California finds that the most frequently occurring cycles of growth in the redwood trees are ten and twenty years. This study of tree-growth has been carried back many hundreds of years in living trees. In addition he has studied the rings of fossil redwood trees going back to an unknown period into the past. Here also he finds a dominance of the ten-year period. Furthermore he finds that increase in rainfall during historic times is closely correlated with tree-growth and must be its principal cause. Hence, the ten-year cycle in tree-growth must represent a ten-year cycle in rainfall. This tree-growth takes place in a region of a marked seasonal change in rainfall, the summers being dry and the winters wet. Hence, increase in winter rain is the chief factor in tree-growth. Any stimulus from solar

changes in summer would exert little influence on tree-growth in California. Hence, to produce a marked cycle effect the solar change would need to be in unison with the annual period.

This cycle of ten years is also shown in the price of certain commodities. In a Foundation report on cycles printed from a report on the "Causes of Economic Fluctuation" by Wilford King a plot of the wholesale price of sheep from 1890 to 1940 is shown. This plot shows maxima in the price about 1900, 1910, 1920, 1930, and 1940. Minima occur about 1896, 1905, 1914, 1923, and 1925. Since abundance and scarcity of supply play a large part in determining price it seems fair to assume that sheep were abundant about the middle of each decade and scarce near beginning.

Ellsworth Huntington in his recent book, "Mainsprings of Civilization,"* gives a diagram showing that since 1880 maxima have occurred almost simultaneously in abundance of lynxes, of New Brunswick salmon, of caterpillars in New Jersey, of deaths from heart disease in the United States, and of ozone at Paris and London. This fact indicates that they are closely related to some common cause.

The analyses of sunspot periods in Table 5 show that there is a period in sunspots of almost exactly ten years. The method of separating this period of ten years from the period of eleven years was to take the means of nine successive periods. This process not only largely eliminates the period of 11.3 years, but also the period of about 8 years. These means were made progressive by dropping one year at a time and adding another year at the end.

When these means are plotted they show an inverted relation to the curves of abundance and scarcity of mammals and insects with minima and maxima slightly in advance. Or else, the rate of increase of sunspots in the ten-year period is the decisive factor. A plot of the rate of increase is given in Figure 3. This curve shows maxima and

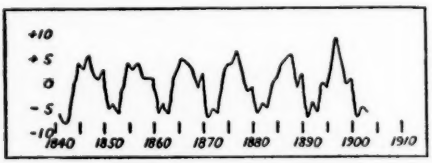


FIGURE 3

minima closely approximating those of the preceding curves. When sunspots are increasing new eruptions are occurring in the solar atmosphere bringing new matter from the interior of the sun, while when spots are diminishing this process is reversed and heated clouds are diminishing in number. From this point of view the rate of increase

*John Wiley and Sons, Inc., New York, 1945, p. 489.

of sunspots is more important in modifying solar influence than is the absolute number of spots.

In 1929 Edgar Lawrence Smith of New York published "Tides in the Affairs of Men,"* in which he pointed out a ten-year period in security prices. This cycle, however, consisted of three maxima and minima of varying intensity in each ten-year period, the cycles having an average length of about forty months or a little less. Mr. Smith pointed out that a similar cycle could be found in the temperature, rainfall, and pressure in New York. Recently he has extended this comparison to the rainfall of Bern, Switzerland, thus indicating that some factor of world-wide variation is involved. A plot of the variations in the price of securities plotted on a percentage scale is given in Figure 4. The maxima and minima of the 40-month period are in-

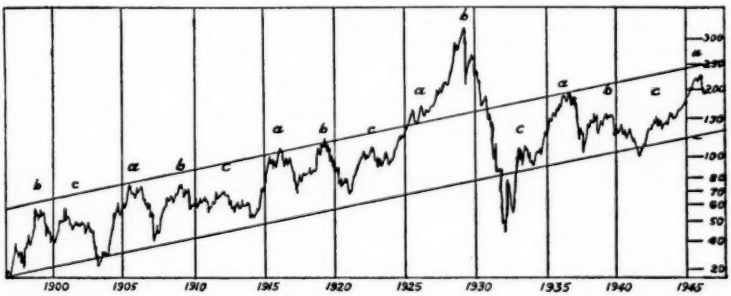


FIGURE 4

dicated by the letters *a*, *b*, and *c*. It will be noted that the intensity of the maxima as well as the length of the cycle varies somewhat from cycle to cycle, but fits closely to a period of about ten years.

These variations in the business cycle are brought about by natural forces independent of politics or social conditions. In a recent publication, "A Calendar for the Business Cycle," Mr. Smith gives a comparison of the variation in prices from 1901-1910 and from 1911-1920.

He says, "These two decades have been chosen because they show clearly the dominating position of the (approximate) 40 months' cycle —three to the decade—that appears to have operated with little distortion in these two decades" . . . "Bearing in mind the great similarity in stock prices in these decades, let us remember 1901-1910 was a period of peace. 1911-1920 included peace, World War I, Armistice, a radical change in the banking system, and yet the patterns of the two decades were noticeably similar.

"Politically the periods differ as follows: From 1901-1909, Theodore Roosevelt occupied the White House, a Progressive Republican elect-

*Macmillan Company, New York, 1929.

ed on the platform of the 'Square Deal' and brandishing the 'Big Stick' against 'Malefactors of Great Wealth.'

"From 1909 to 1913, Taft was president, a non-progressive Republican, unwilling to further the policies of his predecessor.

"From 1913 to 1921 we had Woodrow Wilson, a crusading Democrat. And yet the patterns of the two decades show no disparities which could be attributed to these differing circumstances. . . It is apparent that while certain man-made influences,—such as closing the stock exchange and changing the unit of measurement (the dollar) affects the record of cyclical swings in the values represented in the stock price index, many man-made influences have little or no effect over periods as long as six months—and even fewer, if 12 months or 40 months are taken as measuring points."

The most evident man-made effect shown by security prices is the boom of 1929. In 1927 a confidence in the ability of the newly created Federal Reserve Board to hold credit conditions stable by lowering or raising the legal requirements of the bank reserve as conditions for stability required, led to an optimism in banking and business circles which caused an over extension of credit and a boom in 1929, followed by a marked reaction in 1931 and 1932. Cycles of business activity of pig iron production follow a pattern similar to that of stock prices, but the maxima of the cycles usually lag about a year behind the maxima of security prices. However, when the annual rate of change in percentages of the production in pig iron is computed the maxima and minima come close to those of security prices, except that there was no boom in 1929.

This period averaging about 3.3 years in length was discovered in the growth of trees in the tropics many years ago, by H. P. Berläge, Jr., of Batavia.* He found that the rings in the Djatibaume (date palm) show changes in thickness from season to season in a period averaging about 3.32 years which can be traced for more than 400 years. He gives the successive determinations of the length of this period as shown in Table 6.

TABLE 6

AVERAGE LENGTH OF PERIOD SHOWN BY THE RINGS OF THE DATE PALM

1519-1600	3.44 years
1600-1700	3.28
1700-1800	3.45
1800-1900	2.98
1900-1929	3.87
1519-1929	3.32

The growth of trees depends largely on rainfall which is of a seasonal nature, there being a dry season and a wet season in that region. Since rainfall is closely correlated with pressure a study of pressure

*Gerland's *Berläge Zür Geophysik Bd. 32*, Köppen, p. 225.

changes at Batavia was made in order to get the timing of the changes for comparison with changes in other parts of the world. First the normal annual period in pressure was obtained and then a study made of the observed monthly deviations from normal. These deviations when smoothed gave evidence of a period of about 3.3 years. There are three of these periods in about 10 years, thus closely coinciding with the ten-year sunspot period. This period is not, however, a mathematical period of constant length and amplitude. During a period of 10.5 years it will have a length of about 3.5 years (42 months), while during the following 9.5 years it will have an average length of about 3.1 years, returning to the same phase in 20-year periods. Taken two periods at a time it also shows a fairly regular pattern being 3.5 years for the first seven years and 3.0 years for the following six years.

Both these patterns, the ten-year and the six to seven-year periods return to the same point in 20 years. Hence, 20-year intervals show a more exact resemblance than do 10-year intervals. In 20-year intervals there are six oscillations of pressure averaging about 3.32 years.

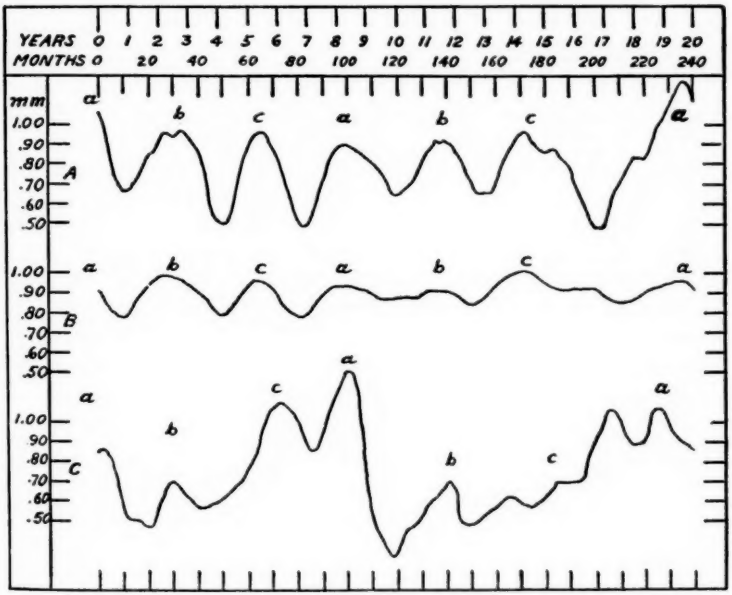


FIGURE 5

Figure 5 gives a plot of the smoothed means of pressure in periods of 20 years from 1866-1940 for Batavia. A similar pattern to that of Batavia is found when twelve monthly moving means of pressure are averaged in 20-year periods for Colombo (Ceylon), 1870-1940 and for

Quixeramobim (Brazil), 1896-1930. The interval of time was so much shorter at Quixeramobim that a fair comparison was not obtained but the same pattern clearly prevails in the tropics from Darwin, Australia, to Brazil. At other stations north and south of the equator like San Diego (U.S.A.) on the north and Santiago (Chile) on the south, the pattern is reversed. That is, maxima of pressure are observed in the same years as minima of pressure near the equator. This distribution of pressure causes a heavy indrought of air into the tropics and a marked increase of rainfall which agrees closely in time with the small maxima of increased sunspots at intervals of about 3.3 years. Other centers of opposing oscillations of the same nature are found farther north. The position of these centers changes with the season, but a full knowledge of their changing positions has not yet been formulated. However, there is a marked tendency for opposing oscillations between the polar basin and centers of oscillation over the oceans about 50° to 60° north latitude in periods of about 3.3 years. A period of 39½ months found by Abbot* is probably the same period although evidence of the change of length between 36 and 42 months has not yet been supplied. From these comparisons the inference is drawn that oscillations in the business cycle follow the same pattern as do climatic oscillations embracing the entire atmosphere of the earth.

At any rate there are small oscillations of sunspots which run closely parallel with the 3.32-year period in terrestrial cycles and it seems almost certain that the causes of these world-wide cycles are associated with changes in the character and intensity of sunlight. Pettit† has shown that changes in ultraviolet radiation are closely related to sunspot variation and Abbot‡ has shown that with increased solar constant there is an increase in the intensity of the blue end of the spectrum. To produce an effect on terrestrial changes these changes must synchronize with the annual period. Plant growth, insect life, and most mammalian life and activity are dependent on the yearly period. Solar activity which closely coincides with the annual cycle in alternate periods of 6 and 7 years and in periods of 10 and 20 years are periods of that kind.

Such periods not only exist in climatic changes and in human activity but also in disease. The researches published by the "Foundation for the Study of Cycles" have brought out many instances of that kind. Wilford I. King gives a diagram of the death rate from whooping cough and of measles in the registration areas of the continental United

*C. G. Abbot, "Periodicities Found in Solar Constant Values," *Annals of the Astrophysical Observatory of the Smithsonian Institution*, Vol. 6, Table 32. 1942.

†E. Pettit, *Astrophysical Journal*, Vol. 75, pp. 370-395, 1932.

‡C. G. Abbot, *Smith. Miscell. Papers*, Vol. 77, Fig. 18, 1925.

States* which shows maxima in the years indicated in Table 7. Severe epidemics occurred in years indicated by italic type.

TABLE 7

YEAR OF MAXIMA OF DEATHS FROM WHOOPING COUGH AND MEASLES IN THE CONTINENTAL UNITED STATES, ARRANGED IN PERIODS OF 20 YEARS, BEGINNING WITH THE YEAR 1900

Whooping Cough	1903	*1906*	1910	1913	1917	1919	1923	1926	1929	1932	1934	....
Measles	1904	*1906*	1910	1913	*1916*	1919	1923	1926	1928	1931	1934	....
Maxima polio	....	....	....	....	1916	....	1921	1925	1927	1931	1935	1937
Maxima polio	1944	*1946*										

A recently published list of cases of infantile paralysis shows a distinct pattern of 10 and 20 years with most of the maxima near those given for whooping cough and measles. These maxima in disease and deaths might be due to an increase in disease-carrying insects, to climatic changes or to a decreased resistance in human beings. Recent researches indicate, however, that they are closely related to new outbreaks on the sun as disclosed by new spots and by highly heated clouds of calcium flocculi. These researches were made by the Dülls† in Germany. It is known that these marked outbreaks on the sun ionize our atmosphere on the same day or the day following down to comparatively low levels and apparently create atmospheric conditions like those of the atomic bomb which are unfavorable to human life. This fact is indicated by the increased death rates shown by the diagram of the Dülls.

An investigation by Edlen shows that these outbreaks form clouds of intensly heated matter in the upper atmosphere of the sun. These clouds are occasionally at temperatures of nearly a million degrees Centigrade and emit radiation of very short wave length, of a nature similar to X-rays or gamma waves. Their effects are most marked on the first day of the outbreaks on the sun. These rays are deleterious to human beings especially to diseased persons. They apparently penetrate the earth's atmosphere and human beings as if these did not exist. Moreover, the fact that the heated clouds can be seen from the

*Wilfred I. King, "The Causes of Economic Fluctuations," Foundation for the Study of Cycles, New York.

†Bernhard and Traute Düll:

(1) Kosmisch Gelenktes Leben, *Deutschen Rundschau*, Jan., 1938.

(2) Erd-und Sonnenphysikalische Vorhänge in ihrer Bedeutung für Krankheits und Todauslösung, *Nosokomeion* (Quar. Hospital Rev.), Stuttgart, 1938.

(3) Zur Frage Solaraktiver Einflusse auf die Psyche *Zeitschrift für die Gesanite Neurologie und Psychiatrie*, Feb. 9, 1938, Berlin.

(4) Ionosphere, Troposphäre, *Die Umschau*, Vol. 26, Frankfurt—M 1939.

(5) Neuer Beitrag Zur Ergaschung des Bioklimas, *Die Umschau*, Vol. 31, Frankfurt—M, 1939.

(6) Kosmisch—Physikolische Storungen der Ionosphäre, Troposphäre und Biosphäre.

(7) *Bioklimalische Beiblätter*, Vol. 6, No. 2, 65-76 and No. 3, 121-134, Vieweg, 1939.

earth and the short waves emitted by them can be measured by a spectroscope is further evidence that they penetrate the atmosphere.

These marked outbreaks on the sun are under study by M. Waldemeir* of the Swiss Federal Observatory at Zurich. His observations fully confirm the existence of these highly heated clouds and of the very short wave radiation first reported by Edlen.

The relation of death rates to solar outbreaks have not been investigated in detail in the United States, but it is worthy of note that the death rate of whooping cough and measles in the United States in ten-year periods comes at the time when the ten-year period in sunspots is increasing most rapidly.

In addition to the ten-year cycle there is also a less marked cycle of about eight years in terrestrial changes and in human affairs. This cycle is fully discussed by H. L. Moore,† one time professor of politican economy in Columbia University in his book "Generating Economic Cycles" and will not be taken up here.

In closing I wish to pay respect to two business executives who have done much to promote the researches described in this paper. The first is John A. Roebling who has encouraged researches in solar relations by grants to the Smithsonian Institution and the second is Copley Amory who has organized conferences of scientific men to discuss biological and other terrestrial cycles and has promoted the organization of a "Foundation for the Study of Cycles." Much credit in promoting these researches should also be given to C. G. Abbot, Ellsworth Huntington, Harlan T. Stetson, and Edward Dewey.

Some Further Facts Suggesting that our Sun is a Variable Star

By H. L. WILLIS*

Mount Rainier in Western Washington is one of the highest mountains in the United States. Its 14,408-foot peak is shrouded in perpetual snow and its slopes are covered with a magnificent system of glaciers. There are seventeen of these glaciers which literally flow down the slopes of Rainier from all sides. These various glaciers are from four to six miles in length and most of them extend far below the snow line. The largest and most typical of these is Nisqually glacier on the south slope. This river of ice flows down the canyon gorge, which it has dug, at the warm summer time rate of sixteen

*M. Waldemeir, Tagligkeitbericht des Arosen Observatorium, *Astron. Mitteilungen der Eidgen*, Sternwarte, Zurich, No. 143, p. 94, 1944 and No. 44, p. 129, 1945.

†Henry Ludwell Moore, "Generating Economic Cycles," The Macmillan Co., New York, 1923.

*Author of "Origin of the Solar System."

inches a day. It flows from near the summit of the mountain at ten thousand feet elevation down to its snout which is only 4000 feet above sea level. Here far below the snow line the daily advance of the glacier is offset by the daily melting and the ice river seems to stand still. Rocks large and small and finer debris fall from the cliffs above on to each side of this half-mile-wide ice river and all this accumulation is carried on down and deposited at the snout, as the ice melts away, forming terminal moraine.

This snout of Nisqually glacier is a huge mud-and-debris-covered ice cliff four hundred feet high. From a huge ice cave at its base bursts the full fledged Nisqually river.

About forty years ago the United States government built an automobile road from Longurier Springs to Paradise Valley which is near the snow line on the south slope of Rainier. This road follows the Snoqualmie River up to near the snout of the Snoqualmie Glacier and there crosses the river by a bridge.

When the author first crossed the bridge shortly after it was built, the snout of the glacier was only about a thousand feet above. The 400-foot ice cliff seemed much nearer. We walked up beside the roaring glacial river to a point near the dirty ice cliff. In 1885 the snout of the glacier was at the very point where the bridge was later built. Terminal moraine far below the bridge gives conclusive evidence that the glacier has been retreating for the past hundred years or more. Now some forty years since the bridge was built the snout of the glacier is more than a half mile above. Thus in the past hundred years or more the glacier has literally retreated many thousand feet up the mountain. This is true of all the glaciers on Rainier. They are all retreating and have been doing this for an unknown, indefinite period.

What is the cause of this? Naturally the answer would be suggested that the climate of western Washington is getting warmer. But how much warmer would the climate have to get to cause Nisqually glacier to retreat more than forty feet a year for many years?

Fortunately we have a weather bureau service which can give us accurate detailed information on this subject. When some old settler remarks that the weather has changed since he was a boy, it is the ordinary weather-bureau man who smiles knowingly and tells him that although successive seasons may be warmer or colder the average stays the same and our weather over a period of years is unchanged.

It was, however, an extraordinary weather-bureau man, Mr. J. B. Kincer of Washington, D. C., who debunked this old weather bureau tradition.

Tacoma, Washington, has had a weather bureau service for only about fifty years. As at all major weather Stations, here are recorded the average monthly and average annual temperature, rain, and snowfall records. The mean temperature for this Station for the year 1892 was 49.9 degrees. For the year 1942, it was 52.6 degrees. In only

fifty years the mean temperature of Tacoma, Washington, has increased 2.7 degrees. A study of the mean annual rainfall records of the same Station by a graph or otherwise reveals that the annual rainfall has decreased from 43.02 inches to 35.02 inches in the past fifty years; an eight-inch or nearly nineteen percent decrease in half a century. Likewise there has been a marked decrease in the snowfall in this city.

Tacoma is fifty miles from Rainier. While we may properly assume that the same increase in temperature has taken place at Rainier as in Tacoma, the rainfall and snowfall on Rainier will be quite different from that at the city fifty miles away at only a few feet above sea level. We may, however, properly assume that the same relative decrease in rainfall and snowfall has occurred at Rainier as at Tacoma.

Here then we have definite accurate records from which we might positively predict, if we did not know, that all glaciers on Rainier would be receding. An increasing temperature would melt them faster; a decreasing precipitation would mean less snow to feed them at the source high on the mountain and smaller glaciers would also melt faster even though the temperature remained the same. Here we have a remarkable demonstration of change of climate at Tacoma, Washington, and nearby Mount Rainier. The weather-bureau thermometer readings and the forty-three foot annual retreat of Nisqually glacier tell the same story. Is this peculiar to Tacoma? Let us see.

In Seattle, Washington, since 1902 the average annual temperature has increased 2.24 degrees. In Portland, Oregon, two hundred miles to the south, the average annual temperature since 1872 has increased 2.46 degrees. Spokane, Washington, has warmed up since 1881 by 2.20 degrees, Los Angeles 2.13 degrees. Cities all over the country show the same phenomena in varying degrees because local conditions of water, mountains, or air-currents come in to modify general conditions.

Thus Minneapolis since 1891 has warmed up only 0.80 degrees; Denver since 1872, 1.30 degrees; Oklahoma City, 2.30 degrees. In St. Louis from 1838 to 1872 the average annual temperature dropped 0.76 degrees but since 1872 has increased 2.40 degrees. Memphis has warmed up in the past eighty-five years by 1.78 degrees; Columbia, 0.61 degrees; San Francisco, 1.25 degrees; Atlanta, 1.35 degrees; New York City, 2.04 degrees; Philadelphia, 2.26 degrees; Boston since 1840, 3.10 degrees; Chicago, 1.49 degrees; Galveston, unchanged for eighty years; New Orleans, 1 degree, Little Rock, 0.9 degrees. These sample points all over the United States prove that the climate of the country has changed. It is warmer by from one to three degrees in practically all areas. But what about the rest of the world? Weather records have been kept in other parts of the world for many years. What do they show?

Johnsburg, South Africa, in the twenty-five years before 1930 warmed up by 0.52 degrees F.; Helwan, Egypt, in the same time in-

creased 1.11 degrees F. in temperature; Havana, Cuba, in thirty-one years warmed up 1.22 degrees F. Greenwich, England, did not follow the general rule. During 1841-1855 it was in a cool period. From 1855 to 1920 the average annual temperature has varied by less than 0.1 degree F. While there has been no increase in the temperature of Greenwich in this 65-year period, *i.e.,* 1855-1920, the whole uniform temperature for these sixty-five years has been 1 degree higher than the cold period ending in 1855. Buenos Aires had a uniform cool period from 1856 to 1895. Since then it has warmed up 0.70 degrees F. Bombay, India, in the seventy years following 1878 has warmed up 1.06 degrees F. Bodo, Norway, in the eighty years following 1868 is warmer by 1.8 degrees F.

In the South Pacific, the great expanse of ocean seems to obscure the general rule. Auckland, New Zealand, has had a mean temperature varying less than a tenth of a degree for the sixty years before 1930. For a few years before 1870 its average temperature was about 1 degree warmer, not cooler, as in some other parts of the world. Adelaide, South Australia, also had a warm period ending in 1865, since which time the climate has been remarkably uniform.

Not many weather bureau records are available prior to 1870. In some of these that go a few years back of this point there are indications that a cool period came to an end about that time when a change to a warmer period set in. The weather records of Washington, D. C., extending from 1817 to date give some interesting and definite information on this point. In the national capital the mean annual temperature decreased from 1817 to 1870, 53 years, by 1.51 degrees F. From 1870 to 1940, 70 years, it increased 2.63 degrees F. Just how long before 1817 the Washington climate had been cooling we do not know. Nor do we know yet how much longer it will continue to rise. Therefore we are as yet unable to see the length of the cycle of cooling down and warming up. Since most of these records of the beginning of the warming up period began around 1870 to 1880, it seems that the cycle could not be shorter than about seventy years. It may be much longer and it may, of course, be irregular.

Here we have then definite, positive, weather records all over the world telling the same story. The only lack of absolute uniformity is in cases like Aukland and Adelaide in the South Pacific, Galveston, Texas, and perhaps a few other places where the proximity of large bodies of water seems to obscure the operation of general conditions. For Galveston, Texas, has had so uniform a climate that the mean annual temperature over ten-year periods has varied less than a hundredth of a degree for nearly seventy-five years.

Since then the weather bureau records have established the indubitable fact that the climate of the whole earth is changing, cooling down and warming up over long periods of years, what possible cause can be assigned for these phenomena?

As stated above let us note that, while 1870 seems to be the turning point, we have no data to show how long before that the cooling down period continued. It may have been not seventy years but one hundred or a thousand years. Nor do we know how much longer the present warming up period may continue. It may be at the turning point now or it may continue for another hundred or a thousand years. Nor do we yet know whether these variations have a uniform cycle or whether they may vary over widely irregular periods.

There was a time several hundred million years ago when the luxurious tropical swamps which produced our coal deposits flourished all over the present temperate zone, when palm trees grew in Greenland, etc. In that Carboniferous Age, the climate of the earth was very much warmer than now; not an increase of 2 degrees or 3 degrees but many degrees. Why did the earth warm up many degrees during the Carboniferous Age? Was it the result of the operation of the same factors which have now in the past seventy years increased the temperature of the whole Earth by as much as 2 degrees F?

Some may assume that the internal heat of the Earth has become more active for some unknown cause and has thus warmed its surface sufficiently gradually to raise the temperature of the air over a period of many years. This seems wholly untenable; since, if it were true, we might expect to find the strata of Earth close to the surface generally warmer than the air. Except under frigid winter conditions, the reverse is true. Further if internal earth temperatures could explain the warming up process it would be far more difficult to explain the oscillation from warmer to cooler.

The Earth three billion years ago in condensing from a gaseous to a molten mass and then through many millions of years to a solid mass did, undoubtedly, make its own climate for unnumbered aeons. In these early times the surface heat of the earth coming from its cooling interior was far greater than that received from the Sun. While the heat received from the sun has supposedly remained constant, the earth's surface heat received from its own cooling has gradually decreased to practically zero. The Carboniferous Age may be explained by this late cooling stage of the earth; but the present condition revealed by weather bureau thermometers and retreating glaciers must have quite a different cause.

When we consider the indubitable fact that the temperature of the whole Earth has increased two or more degrees in the past sixty or seventy years, it would be easy to speculate on the tragic results, if this very slow and imperceptible change of temperature should continue for one, two or ten thousand years. Our descendants a thousand years hence would be living in a very warm world; but in ten thousand years they would long since have perished.

All life on the Earth is dependent on the light and heat of the sun. Not only is thus true, but all life depends upon the further condition

that the temperature range of this heat must be kept within narrow limits. We take these conditions for granted so naturally that it is a shock to realize under what a narrow and critical range of temperature we live. Most men could manage to live, with much discomfort, in climates of 130 degrees F. or of 40 degrees F. below zero. Here is a spread of 170 degrees. Life could not long continue under direct exposure to temperatures of 150 degrees to 160 degrees F. Water boils at 212 degrees F., at which temperature almost all forms of life are killed.

The temperature of the surface of the Sun is about 10,000 degrees F. If this surface temperature should for any reason increase, there would be a corresponding increase in the temperature on the surface of the Earth. If the average temperature in the various latitudes of the Earth were to increase 40 degrees to 50 degrees, it would mean that nearly all land animals in the tropics would become extinct. What are now temperate zones would be sweltering in tropical heat. The ice caps at the poles would mostly disappear, and the temperate regions of the Earth would be pushed far to the North and the South of their present limits. But suppose the temperature of the Earth's surface should rise 100 degrees above the normal for all latitudes. In that case, all life would become extinct except that which could reach and find food around narrow polar regions. An increase of 200 degrees would mean boiling rivers, lakes, and oceans. There would be rain storms of hot water in inconceivably torrential volumes.

This illustrates the narrow, favorable range of temperature under which only we can carry on our normal life. It also illustrates what a wonderful thermostatic arrangement exists on the Sun so that its surface temperature is kept at close around 10,000 degrees F. and therefore the Earth's temperature at close around the very narrow range within which only we may live.

A variable star is one whose brightness or magnitude varies. This dimming and later increase in brightness in some variable stars may be caused by moving interstellar clouds of dust; but most variable stars seem to be such because of some interior conditions not yet understood. A nova, or new star, is a variable star that suddenly bursts into tremendous brilliance, emitting many thousand times as much light and heat as it did only a few days or months before. Such a nova, normally invisible to the naked eye, may become one of the brightest stars in the heavens for a time and then fade away to invisibility. Other variable stars may wax and wane through a very small range of luminosity and heat radiation. We must keep in mind the constant connection between an increased or decreased luminosity and an increased or decreased radiation of heat, except in case of the dust cloud variables.

We do not yet know the conditions under which a star may burst into a nova. But we recognize that, if the Sun should ever abandon the sedate and even tenor of its ways and burst into a nova, all life on the

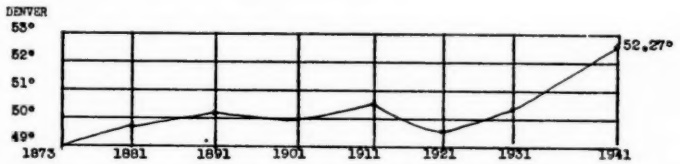
earth would quickly become extinct. The "End of the World" as preached by some religious sects would indeed have arrived. All rivers, lakes and oceans would not only become floating clouds of vapor but the water would be broken up into its component parts of hydrogen and oxygen. The surface rocks would melt and the high temperature of the scorched and blistered Earth would extend far below the surface. But for the past three billion years there is no evidence that any such thing has happened. Our Sun therefore seems to have maintained his good record of sterling, dependable character for a very long time. In fact when we consider under what a narrow range of temperature life exists on the Earth and when we learn from geology that life has been continuous on the Earth for untold ages, the question of whether our Sun is a variable star would seem to be answered immediately and categorically in the negative.

All variable stars that we know have more or less regular or irregular periods. Different stars may vary through several magnitudes or through only a part of one magnitude. The time required to change from bright to dim and back again to maximum luminosity may vary for different stars from a few hours to several years, or a star may shine at uniform brightness for many years and then begin to vary. With our present method of observation it would be difficult to detect a variable star with a very small degree of variability, say one-fiftieth or one-hundredth of a magnitude, much less still smaller variations. And yet there is no reason to doubt that stars with such small degrees of variability do exist. They are like the tiny planetoids of the Solar System that remained undetected for so many years. We have not found these stars of such small degrees of variability because our methods of observations are yet crude. Also the period required for the change of luminosity in the stars so far studied has been small, only a few years for the longest. Only the most conspicuous variable stars have been noted and studied for several hundred years. Any star that varied by one-hundredth of a magnitude during a period of five hundred years would probably escape detection for another thousand years.

What I am trying to show is that it is very reasonable to suppose that there may be many stars with a very small variation in luminosity that may have more or less regular periods extending to hundreds or even many thousands of years. Such stars could not be detected except through very accurate methods of measuring luminosity extending over periods of hundreds of years. When we come to know more of the fundamental building blocks of the universe, electrons, protons, etc., and their reactions under varying conditions, we may discover that this characteristic of variability of luminosity, is an inherent part of every star; that there is no such thing as a star of absolutely constant magnitude. We may then see how the same factors limited by other conditions may produce tiny variations in one star and a nova in an-

other; just as a wind of uniform velocity limited by the presence or absence of other factors may ruffle the surface of a small lake or produce mountainous billows in the ocean.

Now if our Sun were a variable star and should increase its luminosity and hence radiation of heat by a very small amount, this would mean a small increase in the temperature of the earth. In fact temperature of the Earth's surface would increase and decrease with the slowly increasing or decreasing luminosity and radiation of the Sun. But to look at the problem from the opposite direction, since the Earth has actually warmed up from a cool point since seventy-five years ago and before that point was cooling down, what more logical explanation can be given than that our Sun is actually a variable star. It reached a low point of luminosity somewhere around the year 1870 to 1880. Since then its luminosity has been very slowly increasing with a correspondingly slow increase in heat radiation as shown by the slow rise in the temperature of the Earth.



The accompanying graph, which is typical of other places, of the slow change in temperature of Denver shows how the changes in temperature come in peaks and hollows. These peaks and hollows represent ten-year averages. A more realistic graph would show the change each year over a period of seventy-five or a hundred years. Such a temperature curve showing the annual peaks and hollows would give a truer picture of what is actually happening. Again it will be noted that the period from 1921 to 1941 was a time of sharp upward motion of the temperature curve.

Attention is further called to the significant fact that the light curves of some variable stars correspond in a general way to this temperature curve. The conclusion is irresistible that our sun is a variable star. It seems to be a very long-period variable with very small range. In passing from these maxima to the minima it has the characteristic irregular movements or pulsations. In the August (1947) number of Popular Astronomy Mr. James C. Bartlett published a paper on the subject "A New Aspect of the Sun as a Variable Star." He notes what he calls the granular appearance of the surface of the Sun and describes how this varies. He connects this varying granular appearance with the sunspot cycle and suggest that the two may have a common cause.

I need briefly to add in a little greater detail what has already been

stated earlier in this discussion. All data showing the increasing temperature of the Earth have been taken from the Weather Bureau records of the U. S. Department of Commerce, and from similar records of other countries all over the world, as furnished by the Department of Commerce at Washington, D. C. These various weather stations throughout the United States and the world keep daily records of the maximum and minimum temperatures as well as of rainfall and other weather data. These average daily temperatures are averaged for each month and for the whole year. Thus the average annual temperature of each of the many stations throughout the world is on record back to the time of the establishment of each particular station. The common practice of most countries of exchanging weather data makes such information on world weather available at Washington, D. C.

The Planets in September and October, 1948

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. During this period the sun's southward shift in declination will be the most rapid and noticeable. By the end of October the sun will be 14 degrees south of the equator—almost two-thirds of the way to its winter extreme. The equinoctial crossing will occur on September 22 at 9 P.M.

Moon. The phases of the moon will occur as follows:

New Moon	September	3	5 A.M.
First Quarter		10	1 A.M.
Full Moon		18	4 A.M.
Last Quarter		25	11 P.M.
New Moon	October	2	2 P.M.
First Quarter		9	4 P.M.
Full Moon		17	8 P.M.
Last Quarter		25	8 A.M.
New Moon		31	12 P.M.

The last-named phase will cause a total solar eclipse to be visible in the antipodes. A daylight occultation of Mars will be visible from all of North America on the afternoon of September 6. Perigee will occur on September 3, and on October 1 and 29.

Evening and Morning Stars. Jupiter and Mars will continue to be visible in the evening; for early morning observers there will be Venus and, later in the period, Saturn.

Mercury. On September 25 Mercury will be 26 degrees east of the sun. Thus it will be visible in the evening twilight for a week or so before and after that date, but observation will be difficult due to its southern declination.

Venus. As the most conspicuous object in the morning sky, Venus will reach a greatest western elongation of 46 degrees on September 2. It will rise before 4 A.M. during all of this period.

Mars. Although Mars will be still 2 hours east of the sun at the end of this period, it will have become comparatively inconspicuous because of distance and low altitude in the southwest twilight. Of most interest will be its occultation on September 6, and another very close conjunction with the moon on Ocober 5.

Jupiter. On September 12 Jupiter will come to the meridian at sunset, and thus will be very conspicuous in the early evening during all this period.

Saturn. Although practically invisible at the beginning of this period, Saturn, by October 1, will be rising two hours ahead of the sun.

Uranus. On October 6 Uranus will be stationary in right ascension, a few minutes of arc northeast of the star 1 Geminorum.

Neptune. Since it will come to conjunction with the sun on October 5, Neptune will be virtually unobservable during this period.

Department of Mathematics, Temple University, Philadelphia, Pa.
July 1, 1948.

Asteroid Notes

By HUGH S. RICE

Continuing the minor-planet positions for summer observation, we may add two more positions to the ephemeris of 172 BAUCIS as given in the last issue, as follows: for Sept. 6, $\alpha = 21^h\,18^m3$; $\delta = -16°\,56'$; for Sept. 14, $\alpha = 21^h\,13^m6$; $\delta = -16°\,16'$.

80 SAPPHO is in southern Pegasus; its opposition date is August 25 and the photo-magnitude is predicted as 9.3. 694 EKARD is in Pegasus, west of the great square, with opposition August 30 and photo-magnitude 10.1. 796 SARITA is primarily for southern observers, being in Sculptor, southeast of Fomalhaut. Opposition is September 12, and the photo-magnitude 10.1. 119 ALTHAEA is in Pisces and part of the time within the circlet of Pisces. Opposition is September 16 and the photo-magnitude also 10.1. Likely the best asteroid at this time is 8 FLORA. It is well placed for observation, being in Cetus; opposition is September 30, and the photo-magnitude 8.0, the visual magnitude being perhaps 7 to 7.5. 103 HERA is in Cetus, opposition October 1, and the photo-magnitude 9.9.

Positions of BAUCIS and SAPPHO are from the U. S. headquarters, while the rest are from the German asteroid headquarters. In some cases we have had to offer the first or the last positions from our own extrapolation, in order to extend the series, inasmuch as the original ephemerides are only for 5 or 6 weeks, that is, around opposition time.

ASTEROID EPHEMERIDES

For 0^h U.T. Equinox 1950.0

	80 SAPPHO		694 EKARD	
1948	α h m	δ ° ′	α h m	δ ° ′
Aug. 13	22 26.0	+ 8 16	22 41.4	+25 9
21	22 20.8	+ 7 47	22 38.4	+25 24
29	22 14.9	+ 6 57	22 34.7	+25 5
Sept. 6	22 9.2	+ 5 47	22 30.8	+24 10
14	22 4.5	+ 4 26	22 27.4	+22 43
22	22 1.6	+ 2 54	22 24.9	+20 50

796 SARITA

1948	α h m	δ ° ′
Aug. 21	23 48.3	—39 23
29	23 40.7	—39 27
Sept. 6	23 31.0	—39 4
14	23 20.5	—38 5
22	23 10.7	—36 28
30	23 2.8	—34 19

119 ALTHAEA

1948	α h m	δ ° ′
Aug. 21	23 53.8	+ 5 20
29	23 50.0	+ 4 50
Sept. 6	23 44.7	+ 4 2
14	23 38.6	+ 3 5
22	23 32.3	+ 2 3
30	23 26.5	+ 1 0
Oct. 8	23 21.5	0 0
16	23 17.6	— 0 52

8 FLORA

1948	α h m	δ ° ′
Sept. 6	0 43.0	— 6 47
14	0 38.3	— 8 7
22	0 32.3	— 9 17
30	0 25.4	—10 16
Oct. 8	0 18.5	—11 1
16	0 12.5	—11 28
24	0 7.8	—11 34

103 HERA

1948	α h m	δ ° ′
Sept. 6	0 48.8	— 1 15
14	0 44.3	— 2 7
22	0 38.7	— 3 2
30	0 32.5	— 3 56
Oct. 8	0 26.3	— 4 46
16	0 20.5	— 5 27
24	0 15.5	— 5 56

Hayden Planetarium, American Museum of Natural History, New York, July 20, 1948.

Occultation Predictions for September and October, 1948

(Taken from the *Amerian Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1948	Star	Mag.	IMMERSION Green-wich C.T. h m	a m	b m	Angle E from N °	EMERSION Green-wich C.T. h m	a m	b m	Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Sept. 6	MARS	1.5	22 16.9	—2.6	0.0	56	22 49.4	—0.4	—3.3	6
14	40 B.Capr	6.2	0 46.8	—2.0	+0.9	69	2 16.9	—1.9	+0.1	251
15	35 Capr	6.0	4 20.7	—3.6	—2.7	121	4 57.6	+1.0	+2.7	174
28	28 Canc	6.1	6 33.5	+0.3	+1.7	68	7 23.2	—0.6	+0.3	304
28	ν^1 Canc	5.7	7 43.9	—0.1	+2.0	65	8 36.9	—1.1	—0.1	310
28	ν^2 Canc	6.4	8 26.7	—0.2	+2.9	52	9 12.0	—1.4	—1.2	325
Oct. 13	161 B.Capr	6.4	5 24.8	—1.4	—2.7	110	6 5.4	+0.6	+1.8	189
24	BD+27°1337	6.4	7 42.2	—1.5	+1.4	79	9 0.6	—1.9	—0.4	287
26	90 H'Canc	6.1	7 47.4	—0.9	+0.8	103	8 58.2	—1.4	+0.3	290

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

Sept.	6		MARS	1.5	21	31.2	−2.3	−0.5	96	22 42.2	−1.1	−2.0	336
	14	40	B.Capr	6.2	0	9.1	−1.6	+1.6	71	1 36.3	−2.1	+0.9	262
	15	35	Capr	6.0	3	31.2	−2.4	+0.3	87	4 50.1	−1.0	+1.0	213
	28	υ^1	Canc	5.7	7	43.9	+0.7	+2.4	48	8 21.0	−0.8	−0.6	324
	28	υ^2	Canc	6.4	8	24.6	+1.0	+3.9	33	8 50.3	−1.5	−2.1	340
Oct.	10	234	B.Sgtr	5.9	1	2.2	−1.9	0.0	68	2 27.5	−1.6	−0.8	261
	13	161	B.Capr	6.4	5	0.3	−1.7	−0.8	82	6 7.0	−0.2	+0.7	210
	24	BD+27°1337		6.4	7	17.9	−0.7	+1.9	69	8 26.9	−1.6	+0.3	287
	26	90	H'Canc	6.1	7	33.7	−0.3	+1.0	98	8 36.3	−0.8	+0.7	287

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′

Sept.	6		MARS	1.5	21	24.4	−1.8	−1.3	129	22 50.8	−1.9	−1.7	309
	13	40	B.Capr	6.2	23	46.0	−1.2	+0.9	95	1 9.0	−2.2	+1.5	246
	15	35	Capr	6.0	3	8.4	−3.0	+0.3	96	4 27.0	−1.3	+2.0	205
	26	49	Auri	5.0	11	49.4	..	..	15	12 15.7	..	..	341
	27	υ	Gemi	4.2	10	28.9	..	..	25	11 0.2	−3.0	−4.5	337
	28	υ^3	Canc	6.4	8	5.0	+0.5	+1.6	63	8 52.0	−0.6	−0.2	307
Oct.	10	234	B.Sgtr	5.9	0	44.2	−2.7	+0.3	80	2 19.4	−2.0	−0.1	251
	13	161	B.Capr	6.4	4	53.7	−2.9	−1.1	95	5 53.0	+0.3	+2.2	189
	24	BD+27°1337		6.4	6	59.1	−0.7	+1.0	90	8 8.5	−1.2	+1.2	261
	26	90	H'Canc	6.1	7	26.6	−0.4	−0.1	124	8 21.5	−0.3	+1.4	257

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

Sept.	6		MARS	1.5	20	51.7	−0.4	−1.5	161	21 58.8	−2.3	+0.2	278
	11	10	G.Sgtr	5.8	4	50.8	+0.6	+3.9	13	5 14.9	..	..	340
	15	35	Capr	6.0	2	28.1	−1.5	+1.5	77	3 54.1	−2.0	+1.5	243
	15	37	Capr	5.8	8	40.7	−0.8	+0.3	47	9 52.3	−0.7	−0.5	248
	23	14	H'Taur	6.4	9	14.4	−2.3	+0.5	100	10 15.1	−0.5	+3.4	197
	24	BD+24°674		6.3	13	26.6	−2.0	+1.6	49	14 43.4	−1.7	−1.7	285
	25	112	B.Auri	5.7	12	50.2	−3.0	−2.8	131	13 47.0	−2.1	+3.7	210
Oct.	9	234	B.Sgtr	5.9	23	55.4	−2.1	+1.4	71	1 24.0	−2.4	+0.1	281
	13	161	B.Capr	6.4	4	9.9	−1.6	+1.6	37	5 35.7	−2.1	+0.1	252
	21	62	Taur	6.4	12	37.9	−1.8	−1.0	91	13 55.6	−1.4	−0.2	247
	24	47	Gemi	5.6	6	28.7	−0.2	+0.4	118	7 15.3	+0.4	+2.0	232
	24	BD+27°1337		6.4	7	10.0	+0.8	+2.6	36	7 48.4	−1.1	−0.4	315
	27	42	Leon	6.1	13	17.8	−1.3	−1.5	146	14 26.3	−2.1	+0.5	273
	29	10	Virg	6.1	13	38.8	−0.6	−0.6	137	14 43.4	−1.3	+0.2	291

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

"Meteor Notes" this time contains several different things, each of which is briefly described in the proper place, except the table of A.M.S. radiants, containing numbers 3023 to 3034 inclusive. These form a continuation of those given in the last Notes and are derived from observations by Gordon Green and Balfour S. Whitney. I regret the long delay in reducing the radiants of these good observers, but until I can increase my staff considerably such delays are inevitable.

A.M.S. No.	Date	α	δ	No. of Meteors	Wt.	Observer	Remarks
	1937						
3023	Aug. 3.74	31°	+56°.5	4	f. good	G.G.	
3024	Sept. 10.66	49	+44	3	good	G.G.	
3025	July 28.7±	301	— 6	4	f. good	G.G.	
3026	July 27.71	332	—11	3	good	G.G.	δ Aquarids
3027	Aug. 3.74	348	— 7	3	fair	G.G.	
3028	Nov. 24.65	162.1	+63.5	1	good	G.G.	Stationary; +1ᵐ5
	1936						
3029	Aug. 26.83	20	+45	6-7	good	B.S.W.	3 on 26, 3 on 27
3030	Aug. 26.83	28	+30	8	good	B.S.W.	1 on 27
3031	Aug. 22.72	334	— 4.5	4	good	B.S.W.	
3032	Aug. 26.83	349	+ 6	6	good	B.S.W.	
3033	Aug. 26.83	357	+61.5	8	good	B.S.W.	
3034	Aug. 22.72	357.5	0	3	good	B.S.W.	

We have been busy recently following up the brilliant fireball of 1948 June 7, 8:05 P.M., C.S.T., reported first by Tommy Scott. This fireball left a long-enduring train which lasted several minutes. With the invaluable assistance of *Science Service,* already 48 reports have come, with more expected. It is believed that a good solution can be made. If anyone has an observation of this object, please let me have it without delay.

Fireball of 1947 December 6/7

On this date an exceptional fireball over the Gulf of Mexico was reported from two ships and the observations printed in the *Hydrographic Bulletin,* U.S.N. The (abbreviated) reports follow: S1, Second Officer G. D. Chambliss . . . Am. S.S. Quirigua . . . "At 1025 GCT on Dec. 7, 1947, in lat. 27° 30′ N, long. 87° 50′ W, . . . an exceptionally brilliant . . . meteor was observed . . . at h = 25°, bearing 190° . . . moved . . . parallel to horizon to bearing 210° . . . visible fully 6 seconds . . . no trail." S2, Second Officer A. B. Toler . . . Am. S.S. Lake Charles . . . "At 1023 GCT on Dec. 7, 1947, in lat. 27° 40′ N, long. 89° 36′ W, a greenish colored meteor, leaving a blue-colored trail . . . appeared . . . h = 23°, bearing 156° . . . disappeared . . . h = 18°, bearing 129° . . . The trail remained visible about 3 seconds . . ."

A graphical solution, based upon these excellent reports, gave very gratifying results, which are tabulated below:

Date	1947 Dec. 7.43 G.C.T.
Sidereal time at end point	143°
Began over	$\lambda = 88°\ 17'$, $\phi = 25°\ 06'$ at 137 ± 4.4 km
Ended over	$\lambda = 88°\ 19'$, $\phi = 26°\ 45'$ at 50 ± 5.2 km
Length of path	202 km
Projected length of path	183 km
Observed velocity (one estimate only)	34 km/sec (uncertain)
Radiant (uncorrected)	$a = 359°$, $h = 25°$; $\alpha = 144°$, $\delta = -37°.5$
Zenith correction (parabolic)	—45′
Radiant (corrected)	$\alpha = 144°$, $\delta = -38°$
(This radiant is A.M.S. No. 2310)	
Orbit: $i = 99°$, $\Omega\delta = 74°$, $\pi = 74°$, $q = 0.98$	

Fireball of 1943 July 19/20

On this date a bright fireball (A.M.S. No. 3547) was observed by four men at about 9:20 P.M., E.S.T., in all cases to the north-east. Three men plotted the path, one described it only. However, when a solution was tried, it was found that one observer must have misidentified his comparison stars as computation, checked

A.M.S. No.	Date 1900+			Hour; Time Belt		Max. Magn.	H_1 km		H_2 km		Train	Notes	References	F.O. Rep.
3502	25	12	29	5:26	+5	½M	103	± 11	66	± 1.6	20M	(W. J. Fisher's data)	*P. A.*, **34**, 427, 1926	
3503	28	5	22	11:58	+5	—15						flares, L = 500± km	*P. A.*, **51**, 43, 1943	64, 2
3504	29	8	15	8:28	+5	— 3			62.0	± 7.2			*P. A.*, **46**, 272, 1938	46, 17
3505		11	8	9:15	+6	br			30			exploded	*P. A.*, **38**, 114, 1930	8, 7
3506	30	5	21	11:00	+6	— 1			24.7	± 2.5	2 min.	No. 967	*P. A.*, **38**, 442, 1930	8, 22
3507		8	20	14:52	+8	— 7			48.8				*P. A.*, **46**, 273, 1938	46, 18
3508	31	6	3	12:30	+5	br			92.1	± 6.7	30 sec.	No. 1003	*P. A.*, **39**, 605, 1931	12, 37
3509		9	16	9:45	+6	— 4	169.3	± 20.3					*P. A.*, **46**, 273, 1938	46, 18
3510		11	23	7:38	+5	br			>60				*Proc. Pa. Ac. Sci.*, **6**, 1932	
3511		11	23	9:15	+5	br	160		21		no		*Proc. Pa. Ac. Sci.*, **6**, 1932	
3512	32	4	7	12:42	+5	br			90	± 24		burst	*P. A.*, **53**, 136, 1945	66, 4
3513	33	7	25	10:21	+6	— 3	116	± 63	59	± 22			*P. A.*, **52**, 193, 1944	65, 11
3514		9	12	4:30	+6	br					no		*P. A.*, **52**, 193, 1944	65, 10
3515	34	2	2	9:50	+5	bt	130	± 2	?		no		*P. A.*, **50**, 329, 1942	63, 21
3516		3	18	8:35	+7	br	83		30		few sec.	sounds	*P. A.*, **42**, 396, 1934	26, 31
3517		4	5	16:24	+6	— 5	169		82		yes	burst	*P. A.*, **50**, 498, 1942	63, 35
3518		6	6	11:08	+6	br			low			burst	*P. A.*, **51**, 451, 1943	64, 25
3519		12	3	13:50	+6	br			20		long?	sounds, burst	*P. A.*, **51**, 452, 1943	64, 27
3520	35	10	24	17:11	+5	— 5					no	partial solution	*P. A.*, **51**, 453, 1943	64, 27
3521	36	5	4	15:	+5	>M			20±		few sec.	almost horizontal	*P. A.*, **51**, 508, 1943	64, 29
3522		10	16	4:50	+6	— 5					no	exploded	*P. A.*, **51**, 511, 1943	64, 32
3523		10	21	14:24	+6	bt					11 min.	Orionid, No. 1214	*P. A.*, **52**, 93, 1944	65, 5
3524		10	22	5:52	+5	— 6					no	not Orionid	*P. A.*, **52**, 93, 1944	65, 5
3525		10	22	12:00	+4	br					30 min.	Orionid; No. 1216	*P. A.*, **52**, 93, 1944	65, 5
3526		10	23	15:15	+5	— 5					3 sec.	"	*P. A.*, **52**, 93, 1944	65, 5
3527		10	27	9:05	+5	— 4					no	not Orionid	*P. A.*, **52**, 93, 1944	65, 5
3528		10	28	7:53	+6	—12			27	± 11	4 sec.	" "	*P. A.*, **50**, 557, 1942	63, 40
3529	38	1	19	8:38	+6	— 5						no solution	*P. A.*, **48**, 379, 1940	52, 18
3530		5	25	11:26	+5	—15					8 sec.	" "	*P. A.*, **52**, 298, 1944	65, 15
3531		6	4	14:05	+2	br			36.5	± 0.8	6 sec.	flash	*P. A.*, **48**, 379, 1940	52, 18
3532		7	26	15:24	+6	— 5						exploded, no solution	*P. A.*, **48**, 379, 1940	52, 18
3533		11	4	8:25	+5	br					4 sec.	exploded	*P. A.*, **52**, 41, 1944	65, 1
3534		11	24	3:42	—1	br	84	± 09			25 min.	No. 1263	*P. A.*, **48**, 380, 1940	52, 19
3535	39	9	16	15:06	+5	br	72	?	47	?	sev. sec.	v. slow, exploded	*P. A.*, **48**, 204, 1940	52, 12
3536	40	1	23	20:30	+6	gt			0		?	exploded, smoke	*P. A.*, **48**, 261, 1940	52, 13
3537		3	22	7:22	+5	br					15 min.	No. 1294	*P. A.*, **51**, 95, 1943	64, 4
3538		9	22	9:27	+5	<M			30	± 10	?	burst	*P. A.*, **50**, 154, 1942	63, 9
3539	41	1	21	15:14	+5	bt	140		*			burst	*P. A.*, **52**, 299, 1944	65, 15
3540	43	6	21	9:11	+5	— 4						no solution	*P. A.*, **53**, 237, 1945	66, 14
3541		6	21	9:	+5							" "	*P. A.*, **53**, 237, 1945	66, 14
3542		6	21	9:	+5							" "	*P. A.*, **53**, 237, 1945	66, 14
3543		6	21	9:	+5							" "	*P. A.*, **53**, 237, 1945	66, 14
3544		11	24	1:52	+5	br	74	± 16	*			not Bielid	*P. A.*, **53**, 184, 1945	66, 9
3545	44	4	9	7:11	+5	br	50	± 8	50	± 8		exploded	*P. A.*, **53**, 402, 1945	66, 22
3546		10	22	14:04	+5	— 8					10 sec.	not Orionid	*P. A.*, **53**, 37, 1945	66, 2

by the large celestial globe, put the path below his horizon. We are hence not able to use his coordinates further than to know that they indicate a short and low path in the N.E. A good deal of time was spent trying to derive a good solution. This was not realized. The best approximation as to heights, which *may be* fairly good, are: began at 106 ± 19 km over $\lambda = 69° 46'$ W, $\phi = 42° 29'$ N, ended at about 18 ± 2 km somewhere farther north, but place quite uncertain. The length of path and radiant therefore cannot be found.

The fireball was estimated as —4 magn. from near Philadelphia, and —4 rising to —6 from New York City. The New England observers did not give numerical values, only reported it as very brilliant. It was greenish-white in color and the train lasted only a second or two. It was pear-shaped, and the longest estimate of visibility was 4 seconds. The key report was by A.M.S. member Kenneth Weitzenkoffer of New York City, the other two used were by Dr. Harold Bowditch of Brookline, Mass., and by Leo E. Burrill of Lynn, Mass.

At 9:26 P.M., from Mountain Lake, Va., $\lambda = 80° 31'$ W, $\phi = 37° 15'$ N, Dr. I. F. Lewis saw another beautiful fireball, starting at Polaris, crossing γ Cass. and ending just under α Cass. This was white with red coruscations, moved slowly (about 3 seconds), and may have gone lower than reported as trees interfered near the end. He said this was the brightest fireball he had ever seen. This fireball, however, cannot be the same as that seen over New England, even if an error of 6 minutes in time were admitted, as its path began due north of the observer and went towards the N.E.

Assignment of Numbers to Previously Published Fireballs

In the Meteor Notes for January, 1946, a list of all the fireballs for which radiants had been determined by me was given and A.M.S. radiant numbers assigned. These ran from No. 2229 to 2309 inclusive. I have a supplementary list, mentioned indeed in the above as existing, for which, even though radiants could not be determined accurately, if at all, yet it seems wise to assign A.M.S. numbers so that each case can be readily referred to.

The table on the preceding page gives the essential data for these fireballs. The numbers in column 1 are the newly assigned A.M.S. numbers, those in column 8 are the numbers which appear in the long-enduring train tables of Flower Observatory Reprints Nos. 60 and 69. In column 4, br means brilliant; bt, bright; gt, great or very large. It is suggested that persons, who have occasion to use the A.M.S. publications of previous years, enter these numbers from column 1 in their appropriate places.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.,
June 22, 1948.

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

The Cavour, South Dakota, Aerolites (980,442)

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ABSTRACT

The Cavour, Beadle County, South Dakota, aerolites (C.N. = 980,442) belong to a shower of at least 7 stones. The description based on one of them shows that the fall is an old one, because the specimen is badly oxidized. Analyses are given (in Table 1) of the soluble silicate, insoluble silicate, and metal. The last-named component is present partly in the form of small plates, in addition to the more common irregular grains. The stone is probably a brecciated crystalline chondrite (symbol = C,kb).

The Cavour, Beadle County, South Dakota, aerolites (C.N. = 980,442) are members of a shower of at least 7 complete stones, and fragments of probably 2 others. The complete specimens weigh as follows: 12.5 lb.; 9 lb.; 8 lb., 6 oz.; 8 lb. (2 specimens); 5 lb.; and 1 lb. The following description is based on the 5-lb. specimen only. The others have not been seen by the author.

These meteorites were first mentioned by Mrs. W. J. Lindsey of Cavour, South Dakota,[1,2] but they were erroneously described as *siderites* (Si), on the authority of a Dr. Over of the University of South Dakota! It is possible that *one* of the specimens *is* actually a siderite; their high specific gravity and rusty appearance might easily lead to the supposition that they are siderites. The specimen described here was discovered after the publication of the early reports, and was purchased from Mrs. Lindsey by myself. This specimen was found on a farm 11 miles south, and 1 mile west, of the town of Cavour, Beadle County, South Dakota. Some or all of the other specimens appear to have been found nearby. This location is close to the Sanborn County line, so that some of the specimens may be (or may have been) found in Sanborn County. According to Dr. Frederick C. Leonard, the coördinate number (C.N.) of this fall is 980,443[1,2] or 982,442:.[3] In my opinion, the C.N. should be probably 980,442, at least for this 5-lb. stone.

The weight of this stone, as received, was almost exactly 5 lb., but originally it must have weighed somewhat more, as pieces of it have spalled off in several places, especially near one end. This condition is the result probably of oxidation. The stone is irregular, but shows no signs of a secondary crust. Most of the crust is intact, and, altho thickly beset with small "pimples," it shows no sign of orientation or flight markings. There are, however, a few shallow pits a centimeter or so in diameter. The crust is thin, lusterless, and dark rusty-brown in color.

After the stone was cut into slices, it was seen that oxidation had removed the iron and troilite particles to an average depth of 2 to 3 mm., altho in some places penetration was hardly apparent, whereas in others oxidation had penetrated to a depth of 14 mm.; this was most pronounced where spalling had

occurred. From the distribution of the spalled areas, and the depth of the oxidation, it seems likely that this stone had lain in the earth for a long time, with one side at, or close to, the surface, so that this side was less exposed to the action of moisture than was the remainder. Cracks or veins are present, and were visible on the surface before cutting, but it is not certain that they were originally so present, as they have the appearance of having been widened by the expansion consequent to the conversion of the metal into oxide. Oxidation has followed some of these cracks, and, in one case, the metal has disappeared to a depth of 2 mm. on each side of the crack.

The interior of the stone is blackish-brown on fresh fractures, but, on polished surfaces, it has a very dark-gray color, appearing almost black, except in strong sunlight. The whole stone is probably more or less impregnated with oxide. Metal particles seem to be abundant, mostly in the form of small, irregular patches. In places they have the appearance of relatively long rods, but, in consideration of the improbability of cutting slices parallel to rods, they must have the form of plates. Some are very large. The largest found measured 11 mm. on one section, and could be traced thru 3 successive sections, totaling about 2 cm. One was isolated from material ground for analysis. This was 16.5 mm. long, 5 mm. wide, and a little over 1 mm. thick. Another, which appeared on one side of a slice, had a length of 17 mm., and was 1.5 mm. wide at the widest point. Parallel to it was a thin, discontinuous plate. Particles of troilite are visible, but are small and inconspicuous. In a private letter, Dr. H. H. Nininger tells me that he has found similar inclusions in the stones of Marsland, Nebraska; Hayes Center, Nebraska; Holyoke, Colorado; Channing, Texas; and Hatfield, Wyoming. I have seen them in the stone of Elm Creek, Kansas. These plates differ from the metallic veins such as may be seen in Farmington, Kansas, in that they are, in general, thicker; they start and end abruptly; and they are independent of veins in general.

Careful examination of polished sections of the stone in a strong light discloses that it is a breccia, the fragments being apparently all of one kind. They are rounded or subangular in shape, and vary in size, from a millimeter or less to several centimeters in diameter. The material between the fragments seems to be of the same character as the fragments themselves, altho, in the narrowest interstices, it tends to be black in color, and perhaps poorer in metal. This condition may be a result of oxidation.

Attempts to prepare thin sections of the stone were unsuccessful, because of its tendency to crumble when sawed; consequently, no petrographic data are available.

Chondri, mostly 1-2 mm. in diameter, are very numerous; in fact, the stone is composed almost wholly of them. In no case are they conspicuous, and they can be discerned best thru the tendency of the metallic grains to cluster around them. Some seem to be elliptical in shape.

The stone has been analyzed by Mr. F. G. Hawley. Insofar as possible, he avoided material that seemed to be most badly oxidized. The results of his analysis are as follows:

TABLE 1

	Soluble Silicate	Insoluble Silicate		Metal
SiO_2	23.94%	57.70%	Fe	87.58%
TiO_2	.....	0.07	Ni	10.14
Al_2O_3	1.12	4.95	Co	0.61
Cr_2O_3	.....	0.66	Cu	trace

	Soluble Silicate	Insoluble Silicate		Metal
Fe_2O_3	25.68	.....	S	0.48
FeO	5.92	8.72	P	0.07
NiO	1.19	.....		
MnO	1.64	.....	Total:	98.88%
MgO	24.52	20.29		
CaO	1.26	5.17	Pt metals:	0.04 oz./ton
Na_2O	.....	0.68	Soluble silicate:	46.00%
K_2O	.....	1.02	Insoluble silicate:	35.20
P_2O_5	0.46	.....	Metal:	13.44
FeS	9.99	.....	Troilite:	5.30
Totals:	95.72%	99.26%	Total:	99.94%

According to Mr. Hawley, the low summation for the soluble silicate is due to the presence of combined water. The amount of this was not determined, but a qualitative test showed that it was present; it is combined probably with the Fe_2O_3, and perhaps with part of the FeO, to form rust. Troilite was calculated from the total sulfur content, altho a qualitative test indicated the presence of a little iron sulfate, in the form probably of copiapite, $Fe_4(OH)_2(SO_4)_5 \cdot 18\,H_2O$.

One of the metallic plates was saved from the crushed material used for analysis, mounted in lucite, polished, and etched with picral. Part of it showed practically no microscopic features, but approximately half of the etched surface resembled a rather coarse pearlite, composed presumably of alternate layers of kamacite and taenite. In a few places a suggestion of fine Widmanstätten figures was seen.

In the classificational system of Rose, Tschermak, and Brezina, this aerolite should be classed probably as a "crystalline chondrite, breccia-like," with the symbol C,kb. It is not certain, however, that the chondri have a radiate structure.

Since Cavour is the town nearest the place where these aerolites were found, it is proposed that they should continue to be known as the Cavour, Beadle County, South Dakota, aerolites (980,442).

References

[1] Mrs. W. J. Lindsey, *The Mineralogist*, **11**, 316, 1943; reprinted in *C.S.R.M.*, **3**, 119-20; *P. A.*, **51**, 567-8, 1943.

[2] Mrs. W. J. Lindsey, *The Mineralogist*, **12**, 388, 1944; reprinted in *C.S.R.M.*, **3**, 178-9; *P. A.*, **53**, 40-1, 1945.

[3] Frederick C. Leonard, *Univ. of New Mexico Publ. in Meteoritics*, No. 1, p. 44, 1946.

A Sieve Analysis of Crushed Sandstone from the Canyon Diablo, Arizona, Meteorite Crater

John Davis Buddhue

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ABSTRACT

The impact of the Canyon Diablo, Arizona, meteorite crushed, but did not disperse, some of the white sandstone bedrock. An analysis of the particle-size of this material is given. The finest particles are indistinguishable in size from

particles of "rock-flour." The results of a "Photelometric" determination of the particle-sizes in "rock-flour" also are given.

One of the materials resulting from the impact of the Canyon Diablo, Arizona, siderite is a substance that was originally a nearly white sandstone composed almost entirely of grains of quartz. As a result of the impact, many of the original grains have been shattered, but the resulting material is still moderately coherent, altho some specimens of it may be crushed to sand between the fingers without great difficulty. The material analyzed was sand derived from this crushed sandstone, as a result of handling and other (natural) processes of disintegration. Not any of it was purposely broken up for this investigation.

The distribution of particle-sizes in the original sandstone is unknown, but a less complete analysis of white sandstone from a different level in the Crater was typical of well-sorted sand grains, that is, they were predominantly of one size, with small and approximately equal amounts of smaller and larger grains. In general, this sandstone seems to be finer-grained than that which was crushed. This sandstone was disintegrated by soaking it in acid, followed by the gentlest possible crushing in a mortar.

The method of analysis was the usual one, of placing a sample on the upper one of a stack of screens and shaking the stack in a machine for 30 minutes. Afterward, the fraction retained on each screen was collected and weighed. The screens increased in fineness from the top of the stack downward. All but 2 of the screens were standard Tyler and U. S. screens. The 150-mesh screen is not found in the Tyler or the U. S. series, but it does occur in the British screen series. The 400-mesh screen was an apparently unused screen labeled "400-mesh"; possibly it had been specially prepared, for this size is not usually encountered. The results of the analysis are given in Table 1.

TABLE 1

U.S. Mesh	Size, Millimeters	Weight, Percent
20-30	0.84 -0.59 mm.	14.02%
30-40	0.59 -0.42	12.36
40-50	0.42 -0.297	7.63
50-60	0.297-0.250	14.63
60-80	0.250-0.177	13.40
80-100	0.177-0.149	9.70
100-120	0.149-0.125	5.36
120-150	0.125-0.110	0.21
150-200	0.110-0.074	7.22
200-230	0.074-0.062	1.86
230-325	0.062-0.044	4.36
325-400	0.044- ?	1.24
Under 400	?	7.85
		Total: 99.84%

Examination of the coarser fractions showed that some of the grains were not single particles, but consisted of aggregates of variously sized, smaller grains. Counts indicated that 25%-30% of the 20-30-mesh fraction was composed of these aggregates; similarly, the 30-40-mesh fraction contained 15% to 20% of aggregates. The finer fractions consisted entirely of single grains.

In some cases, the sandstone has been crushed and dispersed in the form of a fine powder resembling tripoli; this is known generally as "rock-flour." The finest fraction of the crushed sandstone is indistinguishable from this material.

Samples tested in a Fisher "Sub-Sieve Sizer" gave 10.8 μ for the crushed sandstone, and 11.9μ to 12.0μ for the rock-flour. These figures are supposed to represent the average particle-size of the powders.

A sample of the rock-flour was tested in a Cenco-Sheard-Sanford "Photelometer." This instrument determines the particle-size distribution in fine powders by measuring the light transmission of a suspension of the powder in a liquid of suitable viscosity at various intervals of time and at a specified level below the surface of the liquid. Stokes' law is involved in the rather laborious calculations, so that the particle-sizes determined are "effective diameters," *i.e.*, the diameters of spheres that would settle at the same rate as the particles actually involved. The results of this work are given in Table 2.

TABLE 2

Diameter Range, Microns	Percent
90-80μ	12.7%
80-70	17.6
70-60	19.4
60-50	8.6
50-40	1.1
40-30	0.5
30-20	5.3
20-10	21.2
Under 10	13.6
	Total: 100.0%

As a matter of fact, 10.4% of the particles were smaller than 7.5μ, but, in consideration of even this fact, the results can be hardly in agreement with the average determined with the "Sub-Sieve Sizer." The cause of the discrepancy is not known, but a similar result has been found with these instruments when powdered potassium perchlorate was used, and in other laboratories when Portland cement-powder was employed. Microscopic examination of the rock-flour revealed numerous grains larger than 10μ, many of them much larger, and to this extent it confirms the "Photelometric" measurements.

My thanks are due to Mr. Austin Herbst for valuable assistance with the laborious calculations involved in the reduction of the "Photelometric" data.

The Russian Meteorite of 1947 February 12

John H. Schilling
522 South Pugh Street, State College, Pennsylvania

ABSTRACT AND INTRODUCTION

Two accounts of the meteorite that fell in the Soviet Far East, on 1947 February 12, as published in the *U.S.S.R. Information Bulletin* of the Soviet Embassy in Washington, D. C., are given.

Notes on Soviet Life, April 16, 1947, Issue:

"A meteorite fell recently in the Ussuri taiga (in the Soviet Far East). The flight of the meteorite was visible within a radius of 125 miles, altho it occurred during the day (10:00 A.M.). The explosions were heard from a distance of 60 miles. Thirty (30) craters, many of them 80 feet in diameter and 30 feet deep, were discovered in the area where the aerolite fell.

"Tons of fragments of the meteorite cover the Earth's surface, but the major mass, weighing evidently several dozen tons, lies 30 feet deep in the ground.

"The Academy of Science of the U.S.S.R. dispatched a special expedition to the place where the aerolite fell. This expedition will make a scientific survey of the phenomenon and take measures to extract the aerolite from the Earth and deliver it, together with the fragments, to Moscow."

Report on a Meteorite, September 10, 1947, Issue:

"The scientific expedition headed by Academician V. G. Fesenkov has returned from its investigation of the meteorite which fell in the Soviet Far East on February 12, this year. The meteorite, which fell in the Sikhote-Alin Mountains (running parallel to the Pacific Coast in the Maritime Territory), was unusually large.

"Academician Fesenkov, noted astronomer and Chairman of the Academy's Meteorite Committee, gave some of the results of the expedition. 'The meteorite had the form of a fireball, behind which stretched a long train, first black and then of a gray color. The flight lasted 4 or 5 seconds, for about 5 miles a second,' he reported.

"The meteorite, fortunately, landed in a dense section of the taiga. The nearest inhabited point was the village of Novopoltavka, about 25 miles away.

"The scientists questioned nearly 300 persons who saw the fall of the meteorite or heard the explosions. The coördinates of the points of the appearance and disappearance of the meteorite were registered with the aid of special instruments. These data helped to determine the orbit of the meteorite's flight in interplanetary space.

"In the vicinity of the fall, the expedition succeeded in finding 106 craters, all of them within a 125-acre area. The diameter of the largest crater was 92 feet, and the depth, 20 feet.

"In addition to the large number of fragments, the scientists collected 256 'individual' meteorites—pieces of the gigantic meteorite which broke off at a great altitude and then followed an independent course thru the atmosphere. The fragments, on the other hand, were formed after the meteorite struck the ground. The 'individual' meteorites weigh from a fraction of a gram to 650 pounds. They are covered with the crust of melting, while the fragments have a rust color and look like clay or stone. Nearly 5,000 tons of clay and shattered rock were blasted out of the largest crater in a matter of seconds, Academician Fesenkov reported."

In *C.M.S.*, **4**, 56-7; *P. A.*, **55**, 329, 1947, an account of this same meteorite, reprinted from *Time*, May 5, 1947 (p. 74), is given. The one discrepancy between this report and the two preceding ones is in the type of meteorite described. The *Time* account states that "fragments of iron, nickel, and cobalt were said to have smashed thru the soil," but the two foregoing accounts state that the meteorite was an aerolite, and that the fragments found resembled stone or clay! Altho the meteorite is probably an aerolite, since the *Time* report was made before the expedition had been sent to examine it, I have written V. G. Fesenkov, the Chairman of the Meteorite Committee of the U.S.S.R. Academy of Science, hoping for further information.

The Norton County, Kansas, Achondritic Fall (1000,400)

The following note on "The Norton County, Kansas, Meteorite," by Lincoln La Paz, appeared in *Science*, **107**, No. 2786, p. 543, May 21, 1948.

"Fragments from the large detonating bolide that startled the inhabitants of several Midwestern States on February 18 were recovered and identified on April 28 by an expedition sent into the field by the Institute of Meteoritics of the University of New Mexico. Most of the specimens so far recovered have been found on one of the farms of G. W. Tansill, in Sections 12 and 13 of Rock Branch Township in Norton County, Kansas, but the largest specimen recovered, a mass weighing over 100 pounds, was recovered on the McKinley ranch in Section 1 of this township. All specimens recovered to date have been either donated to or purchased by the University of New Mexico.

"The Norton County meteorite belongs to the rare class of achondrites, and, while presenting many points of similarity to the remarkable Cumberland Falls [Whitley County, Kentucky; C.N. = 844,368] whitleyite, possesses certain features so distinctive that it seems quite possible that it will serve as the type stone of a new class of achondrites.

"A detailed report on the field survey resulting in recovery of the meteorite, and a description and analysis of the specimens recovered, will be published in the near future."

Altho this fall appears to have covered a considerable area, it may be provisionally assigned the coördinate number 1000,400.

Dr. La Paz Appointed a Regional Director of the American Meteor Society

Dr. Charles P. Olivier, President of the American Meteor Society, has appointed Dr. Lincoln La Paz Regional Director of that society for the area covered by the States of Arizona, Colorado, New Mexico, and Utah. Dr. La Paz, now Director of the Institute of Meteoritics of the University of New Mexico, and an Ex-President and Councilor of the Meteoritical Society, served as Director of the Ohio Section of the American Meteor Society from 1930 to 1942. Dr. La Paz has also been recently coöpted by Commission 22 (the Commission on Meteors *etc.*) of the International Astronomical Union.

Second Notice of the 11th Meeting of the Society

Attention is called to the notice that appeared in the May, 1948, instalment of *C.M.S., P. A.*, **56**, 275, concerning the 11th Meeting of the Society, which is scheduled to be held at the Institute of Meteoritics of the University of New Mexico in Albuquerque, on September 7 and 8, 1948.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: OSCAR E. MONNIG, 1010 Morningside Drive, Fort Worth 3, Texas

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

AAVSO Spring Meeting, 1948: In spite of the inclement weather which had prevailed in New England for some days up to and including the scheduled day of the meeting, members and their friends gathered at South Hadley, Mass., for the 37th Annual Spring Meeting at the John Payson Williston Observatory at Mount Holyoke College on May 21 and 22, to the number of fifty. This was the third Mount Holyoke meeting of the Association, two with Professor Anne S. Young as the hostess, and this one with Professor Alice H. Farnsworth as our hostess, assisted by her assistant, Miss Ruth Hayner, and students.

Once more Ralph Buckstaff of Oshkosh, Wisconsin, held the record for having travelled the greatest distance, with Cyrus Fernald driving from Wilton, Maine, and William Tifft training up from Frederick, Maryland. Besides the regular standbys at these meetings, there were groups from Worcester and Springfield, Mass.

The Council meeting held on Friday evening was very well attended, although we did miss our Secretary, Mr. Harris, and past presidents Charles H. Smiley, who had not returned from the May eclipse expedition to the East Indies, and Dirk Brouwer, who was in Holland.

In the absence of Secretary Harris, Clinton Ford acted as secretary protem, and Dr. Martha E. Stahr volunteered to act as Variable Commentator.

That there is a continuing interest in variable star observing by the amateur is shown by the election of twenty annual members, and four life members. These are listed herewith:

LIFE MEMBERS

Owen Gingerich, Goshen, Indiana
George F. Nolte, New York, New York
Percy W. Witherell, Jamaica Plain, Mass.
Walter P. Reeves, Portland, Maine

ANNUAL MEMBERS

F. N. Aldrich, Hanover, New Hampshire
R. C. Bard, Appleton, Wisconsin
M. Bollar, Cienfuegos, Cuba
C. V. Cain, Minneapolis, Minnesota
H. L. Crawford, Boystown, Nebraska
J. N. Davis, Winchester, Massachusetts
I. P. Debono, Cairo, Egypt
C. L. Dillon, South Gate, California
W. C. Erickson, Duluth, Minnesota
J. L. Holloway, Memphis, Tennessee
A. G. Ingalls, Cranford, New Jersey
R. A. Merklein, Rhinelander, Wisconsin
E. W. Pierson, Hempstead, New York
K. C. Rich, Inyokern, California
J. J. Ruiz, Dannemora, New York
E. J. Rusho, Arvada, Colorado
W. J. Semerau, Alloy, West Virginia
B. A. Smith, Winchester, Massachusetts
S. C. Venter, Pretoria, South Africa
E. C. Waldmann, Brooklyn, New York

Mr. Nolte has been an annual member since before the formal organization of the Association in 1917. Mr. Witherell has been well known to all the members as our true and trusted Treasurer. Three foreign members are noted among the list of annual members, Sr. Bollar from Cienfuegos, Cuba, I. P. Debono of Cairo, Egypt, and S. C. Venter, of Pretoria, South Africa.

The slate of candidates for the Council to be voted upon at the Annual

Meeting, as presented by the Nominating Committee, was accepted. The names of the eight candidates are as follows, four of whom are to be elected:

Harry B. Chase, Quincy, Massachusetts
Ferdinand Hartmann, St. Albans, New York
Margaret W. Mayall, Cambridge, Massachusetts
Walter L. Moore, Louisville, Kentucky
Paul H. Nadeau, Quebec, Canada
J. J. Neale, New Haven, Connecticut
Lois Slocum, Chambersburg, Pennsylvania
Martha E. Stahr, Ithaca, New York.

With reluctance, the Council accepted the resignation of Mr. Hartmann as Chart Curator. Richard W. Hamilton of 4 Union Park, Norwalk, Connecticut, accepted the post of Hartmann's successor, and took over the work as of June 1.

It was voted not to act on the resignation of Mr. Harris as Secretary, but to wait until the annual meeting to choose his successor. In view of the fact that President Marjorie Williams is to spend her sabbatical year in Europe, first vice-president D. W. Rosebrugh was appointed acting president until the October meeting. Mr. Buckstaff was named as chairman of the AAVSO delegation to attend the Astronomers League meeting in Milwaukee in July.

While the Council was in session, the other members of the Association had an opportunity to inspect the well-equipped classroom and laboratory of the observatory and, between clouds, to do some observing with the 8-inch refractor.

The business session was held on Saturday morning in the Mary E. Woolley Hall, with President Marjorie Williams in the chair and Mr. Ford as acting secretary. Professor Farnsworth welcomed those in attendance and made announcements concerning the plans for the day.

The death of two members was announced, William Henry of Brooklyn, New York, and H. Boyd Brydon of Victoria, B. C., Canada.

During the noon hour the Association attended in a body the special session held at the observatory by the college staff when a portrait of Miss Anne S. Young, for 37 years professor of astronomy and head of the observatory, was unveiled and presented to the college by her former assistants and students of astronomy. The portrait was duly accepted by Miss Farnsworth, who after recounting some of the achievements of Miss Young, told us that at that very hour a corsage of orchids was being delivered to Miss Young at her home in Claremont, California. The Recorder spoke of her long connection with the AAVSO, and of her still longer career as a variable star observer. A telegram worded as follows was sent to Miss Young: "Meeting in the Observatory which you headed for 37 years. We miss your presence but are happy to participate in the ceremony in your honor." By a strange coincidence, a telegram was received almost simultaneously from Miss Young, sending greeting for a successful meeting.

The program of papers included one by Miss Stahr, entitled: "The Sun a Microwave Variable—Paper II"; one by Mr. Rosebrugh: "A Chat With Those Present"; and one by Mr. Seely: "Timing Algol." Mrs. Hogg gave a real variable star paper entitled: "Variable Stars in Clusters." C. V. Cain's paper dealt with the trials and tribulations of a new variable star tyro, entitled: "Not in the Annuals."

Mr. Rosebrugh later devoted some few minutes to a talk on: "How High do Birds Fly" and "Solar Granulations." Miss Farnsworth spoke on: "Links

with 1837," tying the observatory in with early solar phenomena. Mr. Heines, besides presenting his solar division report, spoke on "A Preliminary Forecast of Solar Activities, and Solar Bookkeeping." He also exhibited a solar film showing shots taken with the Harvard coronagraph. James Stokley showed two reels of the 1947 Eclipse Expedition to Brazil, as taken by the National Geographic Society.

Following the luncheon held at the "Book Shop Inn," at which President and Mrs. Ham were special guests, the Recorder read a somewhat lengthy paper, "Over the Years," which recounted memories of the early days of variable star observing at Harvard, and of the members of the Association.

The formal sessions adjourned at 5 P.M., to meet again at Harvard on October 15-16. Many members remained over until Sunday, enjoying the opportunity of more star gazing, and sunspot gazing the next morning.

On the whole, the meetings, although not the largest in point of members present, were certainly full of enthusiasm, and bespoke well for the long-continued interest in variable star and solar observing.

Recently Discovered Novae: The discovery of three novae in recent months reveals two of them as belonging to our own galaxy, and the third to one of the external galaxies. Nova Serpentis was discovered photographically at the Abastumani Observatory by Bartay early in May, but word of the discovery did not reach this country until early in June. This nova is not far distant from Beta Serpentis and the long-period variable R Serpentis, and had the region not been unfavorably placed for observation at the time of its greatest brilliance, it might well have been detected by visual observers when observing R Serpentis. In May the nova was of visual magnitude 9.0, probably then about three magnitudes or more below maximum brightness, as indicated by the appearance of its spectrum. Pre-outburst magnitude was fainter than magnitude 14. Visual observations made in May and June indicate that the star is gradually fading in light, but very irregularly. P. Wellmann of the Hamburg-Bergedorf Observatory reports that spectra taken in May correspond closely to those of Nova Puppis 1942 one year after maximum, except for the coronal lines, which in Nova Serpentis appear to be similar to those in the spectrum of RS Ophiuchi, a recurrent nova.

Incidentally, on the day word was received at Harvard of the discovery, Mr. Joseph Gossner, a graduate student at Harvard, independently detected the presence of the nova from an examination of a spectrum plate.

Another photographic discovery of a nova—the one in Cygnus—was made by B. S. Whitney of the University of Oklahoma. On plates taken there June 2 and 3, Dr. Whitney suspected the presence of a 10th magnitude nova, and he requested confirmation by Harvard. This was done on June 4. When discovered, the star was probably nearly three magnitudes below maximum brightness, and the pre-outburst magnitude was perhaps 17. Although not so readily observable visually as is Nova Serpentis, it is being closely followed photographically.

A third nova, this one a supernova in the external galaxy NGC 6946, was detected not far from the nucleus of the galaxy by Dr. Mayall of the Lick Observatory. The appearance of its spectrum early in June suggests a type two supernova several weeks past maximum. Its magnitude was reported at 15.3, and the galaxy in which it occurs is described as very large, though faint, and contains some resolvable stars. The galaxy is situated on the boundary of Cepheus and Cygnus.

Notes on the Variables: Chi Cygni, 194632, is at maximum, readily visible

to the unaided eye. Also, Mira, o Ceti, 0214*o3*, should be well on its way to maximum. SS Cygni, 213843, has been passing through a stage of irregular activity in recent months, somewhat like that of 1938.

Observations contributed during May and June: A total of 7,120 observations was contributed—3,860 in May and 3,260 in June—by 77 observers as follows:

Observer	May—1948—June No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	May—1948—June No. Var.	No. Ests.	No. Var.	No. Ests.
Adamopoulos	..	..	6	6	Lee	..	..	9	9
Ahnert, P.	36	408	39	257	LeVaux	65	161	57	94
Alder	2	4	..	..	Luft	5	11	2	6
Ancarani	18	40	21	38	Miller	16	31	11	17
Ashbrook	..	..	13	17	Massett	4	9	..	..
Bappu, M. K. V.	..	..	11	19	Nadeau	12	12	59	89
Bicknell	..	..	8	55	Oravec	60	202	34	112
Blunck	13	15	18	22	Parker	32	32	26	26
Bogard	28	57	32	81	Parks	24	24	20	20
Boone	..	..	23	23	Pearcy	55	60	66	69
Buckstaff	15	26	9	12	Peltier	89	140	132	208
Cain	14	25	17	48	Penhallow	6	10	6	7
Chandra	116	191	..	..	Pierson	..	..	15	30
Chassapis	32	68	34	92	Plybon	5	14	4	12
Cilley	23	50	..	..	Rakosi	2	3	..	..
Cragg	83	83	30	30	Renner	74	74	110	110
Dafter	..	..	8	50	Rich	2	4	2	3
Daley	5	9	4	8	Rosebrugh	17	101	18	60
Darnell	5	20	4	14	Ruiz	..	..	4	8
Debono	3	10	..	..	Rusho	..	..	2	5
Dillon	5	9	6	13	Schoenke	..	..	3	4
Elias	36	60	..	..	Seagroves	..	..	8	8
Erickson	..	..	31	56	Sill	..	..	9	10
Escalante	38	48	..	..	Slemaker	8	10	9	9
Estremadoyro	7	14	7	7	Smith, B.	..	..	2	4
Fernald	235	491	235	409	Stein	7	15	9	13
Focas	15	22	9	11	Szabadosi	2	2	..	..
Flower	..	..	3	6	Taboada	27	27	37	37
Greenley	..	..	21	50	Tarbell	..	..	13	16
Halbach	..	..	17	17	Thomas	13	13	21	21
Harris	1	1	..	..	Tifft	29	31	35	35
Hartmann	137	160	119	128	Venter	7	16	..	..
Hiett	12	26	9	16	Waldmann	18	40	..	..
Holloway	4	8	6	8	Webb	..	..	18	23
Howarth	14	14	..	..	Weitzenhoffer	9	26	6	7
Hurukawa	12	81	..	..	Wells	5	5	5	5
Kelly	12	12	10	10	Werntz	14	21	..	..
Kirchhoff	35	184	30	141					
Kitley	21	46	..	..	77 totals		3,860		3,260
de Kock	109	585	113	541					

July 15, 1948.

Comet Notes

By G. VAN BIESBROECK

The list of comets under observation has been lengthened by three since the last notes were written: two expected periodic comets have been recovered; the third object is new.

Periodic Comet Neujmin No. 1 (1913 III) was located by S. B. Nicholson on a plate exposed May 6 at the 100-inch reflector of the Mount Wilson Observatory. The brightness, 17.5 magnitude, and the declination of 42° south made this object inaccessible to most observatories. The measures indicate that the comet will pass its perihelion 3½ days ahead of the date 1948 December 19 predicted by the writer's computation based on the two apparitions of 1913 and 1931. The period is 18 years and the eccentricity is very high. But what makes this comet of special interest is its nearly stellar appearance: some observers have considered it as an asteroid but larger instruments have brought out the fact that the coma is not quite stellar and that there is a very faint tail visible at times.

It is fortunate that the comet was located early at its present return because it will remain in an unfavorable position for the balance of the year. Not until 1949 will conditions be more favorable. The comet is designated as 1948 *f* at its present return.

Periodic Comet Forbes (1929 II). From the Lick Observatory came the report of the recovery of this expected comet on May 14 by H. M. Jeffers. It was a very difficult object not brighter than 17th magnitude. The writer recorded it since as a round fuzzy coma but the southern declination made the comet observable only for a short time after sunset.

The object was found within 3′ of the position predicted by F. R. Cripps on the basis of the 6.4-year period indicated by the two appearances of 1929 and 1942. It will be designated as 1948 *e* because its recovery was announced earlier than that of Comet Neujmin. Both objects will remain located in the same region of the sky during the balance of the year.

Comet Honda-Bernasconi (1948 *g*). The first news of the discovery of a 4th magnitude comet on June 2 came through a press report. The discoverer was the Japanese amateur Honda who last year found Comet 1947 *m*. The support that this observer has been given by the occupying forces is evidently well justified. The naked-eye morning object was independently picked up June 4 by the Italian amateur Bernasconi, hence the two names to designate this comet. From accurate positions obtained June 7 to 9 at the Lick and Yerkes Observatories L. E. Cunningham computed a first orbit showing that the comet was due to fade rapidly. From observations covering the period June 7 to 16 the same computer has deduced the following more precise elements:

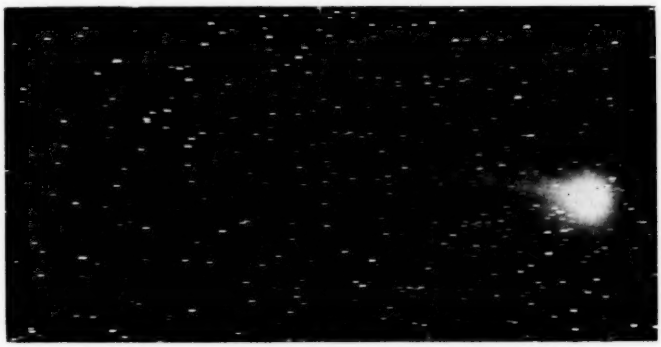
Perihelion passage 1948	May 15.90624 U.T.	
Node	203°.13279	1948.0
Perihelion to node	317.04328	
Inclination	23.16174	
Perihelion distance	0.2077072 Astr. Units.	

These give the following ephemeris for August:

	α	δ	Magnitude	
	h m	° ′		
1948 Aug. 5	18 54.7	+21 31	10.2	11.9
13	48.5	17 14	10.8	12.6
21	45.7	13 41	11.3	13.3
29	45.4	10 44	11.8	14.0
Sept. 6	18 47.0	+ 8 16	12.3	14.6

The brightness is predicted under both assumptions of a variation according to the 4th and the 6th power of the distance from the sun. Actually the brightness has shown considerable fluctuations. When last recorded here the total brightness was 9th magnitude (July 10). It was a fine object in the early nights after

the discovery: the tail was well visible to the naked eye. Its complex structure is illustrated by the accompanying Figure from a 10-minute exposure obtained June 13 with the 24-inch reflector of the Yerkes Observatory.



COMET HONDA-BERNASCONI (1948 *g*)

Most of the comets observed earlier in the year are now too faint except for the most powerful telescopes. Two of them remain in reach for some time. In the early hours of the night COMET BESTER (1947 *k*) gradually diminishes in brightness: it was recorded here as a coma of about 15th magnitude on July 3 and still showed a short tail. COMET PAJDUSAKOVA-MRKOS (1948 *d*) came within less than 6 degrees from the pole in June and remains circumpolar for several months more while slowly losing in brightness as shown by the following ephemeris by Schmitt:

		α	δ	
		h m	° ′	Mag.
1948 Aug.	5	10 44.0	+75 46	11.2
	13	44.9	74 55	
	21	47.4	74 23	
	29	10 50.8	+74 10	11.4

Williams Bay, Wisconsin, July 12, 1948.

General Notes

Mr. Harry E. Burton, who retired June 30 after nearly forty years' service at the U. S. Naval Observatory, died July 19. His position from 1929 until his retirement was principal astronomer as head of the Equatorial Division.

The Computation of Orbits,—This is the title of a new book by Dr. Paul Herget, director of the Cincinnati Observatory, which will be avaliable by September 1. It will contain, among other material, a discussion of problems in practical astronomy, the two body problem, a description of the classical methods of orbit computation by La Place, Gauss, and Olbers, perturbations, and the necessary tables. Such a book is badly needed and will be eagerly awaited by those concerned.

Palomar Observatory Stamp Announced

Postmaster General Jesse M. Donaldson announced recently the issue of 50,000,000 of the three-cent Palomar Mountain Observatory commemorative postage stamp which is to be placed on first-day sale at Palomar Mountain, California, on August 30, 1948.

Samuel R. Young, Executive Assistant to the Postmaster General and a member of National Capital Astronomers of Washington, D. C., has been designated to represent Postmaster General Donaldson at the Palomar Mountain Observatory ceremonies when the new stamp is placed on first-day sale. Mr. Young has gained considerable reputation as an amateur astronomer.

Stamp collectors, astronomers, scientists and others desiring to obtain first-day cancellations of this new stamp may send not in excess of 10 self-addressed envelopes to the Postmaster at Palomar Mountain, California, with postal note or money order remittance to cover the cost of the stamps to be affixed.

The Cleveland Astronomical Society Meetings

The speaker at the meeting of the Cleveland Astronomical Society held on May 28 at the Warner and Swasey Observatory of the Case Institute of Technology was the Society's founder and long-time president, Dr. J. J. Nassau, who spoke on "The Golden Age of Astronomy." As expected from previous performances, his talk proved to be very interesting and full of humor.

Dr. Nassau chose the 25-year period ending with the present as the "Golden Age." This was especially appropriate as the Society recently celebrated its twenty-fifth anniversary. A review of the most important work done on the sun during this period opened the lecture, with Lyot and the coronagraph given special mention. Kuiper's recent work dominated the section devoted to the planets, particularly his discovery of the fifth Uranian satellite and his investigations in the infra-red region of the spectrum with a lead-sulfide cell on the composition of the Martian polar caps and the Saturnian rings. The development of the picture of galactic structure and the observational and theoretical evidence pertaining to the expanding universe completed the presentation. Here the contributions of Shapley and Hubble were stressed. Several astronomers were lauded for their part in the advancement of astronomy, particularly Hale and Russell. If a "giant" of the age were to be singled out, however, the speaker mentioned Einstein as his choice.

During the lively discussion which followed, it was brought out that the term "Golden Age" might also be applied to the 17th century era which included Kepler, Galileo, and the giant Newton.

After the discussion the annual election of officers was held with the following results: President, Dr. J. J. Nassau; 1st V.P., Dr. S. W. McCuskey; 2nd V.P., Mr. E. N. Jennison; Secretary-Treasurer, Mrs. S. K. Towson; Recording Secretary, Paul Annear.

The Cleveland Astronomical Society held its annual dinner meeting at the Church of the Cross on June 11, 1948, with about 100 members and guests present. After the dinner, the group adjourned for a short time and rode or walked the short distance to the Warner and Swasey Observatory, where the speaker for the evening was Dr. Roy K. Marshall, Director of the Fels Planetarium in Philadelphia. His topic was "Great Moments in Astronomy," and he used the flash-back method very effectively to highlight the work and personalities of such men as Eratosthenes, Tycho Brahe, Galileo, Kepler, Newton, Adams, Leverrier,

Huggins, Curtis, Lowell, W. H. Pickering, Shapley, Hubble, and others. The speech is to be published in this magazine in the near future.

The lecture was thoroughly enjoyed by the large crowd, and fitted in very nicely with that given by Dr. J. J. Nassau at the previous meeting, "The Golden Age of Astronomy."

A Preliminary Forecast of Solar Activity

The provisional sunspot numbers as published monthly by the Zürich Observatory indicate that the maximum of the present solar cycle occurred in May, 1947, and that the highest smoothed relative sunspot number was 156.1. This figure means that we experienced, last year, one of the highest maxima in sunspot history, which has been exceeded in height only by the maximum of 1778. (The highest smoothed relative sunspot number of the maximum of 1778 was 158.5.)

The unusual height of the maximum of 1947 was not at all surprising; for I had predicted in 1941, some years before the beginning of the present sunspot cycle, that with a high degree of probability a very high maximum was to be expected. Like this prediction all the other predictions concerning the present sunspot cycle, which I have published in the September, 1942, and July, 1944, issues of the *Astrophysical Journal,* have come true. I think this was the first time that the probable features of a solar cycle could be forecast before its beginning.

Now, the following predictions can be made about the future course of sunspot frequency:

It is very probable that during the coming years solar activity will decline so slowly that not before May, 1952, will the smoothed relative sunspot numbers fall below a quarter of their last maximum value, *i.e.,* below 39. After this time, however, minimum will come soon; it will occur very probably within 20 months after the month in which the smoothed relative sunspot numbers have fallen below 39. In view of the shortness of this interval it seems unlikely that the minimum will be a deep one. From the minimum, the next solar cycle, the nineteenth in the Zürich series, will start, and it can be expected that solar activity will again show a very steep ascent to a maximum of great intensity. For it is very probable that in Cycle No. 19 the smoothed relative sunspot numbers will rise from a quarter of their maximum value to the maximum within less than 32 months and that their maximu value will exceed 128.

As these predictions are based upon provisional values of the epoch and the height of the 1947 maximum they have only a preliminary character. There is no doubt, however, that they will not undergo essential alterations when the provisional numbers are replaced by the definitive ones.

I think the above predictions will be welcomed by the members of the AAVSO Solar Division. For sunspot observers generally do not like quiescence on the sun, and my predictions give us the hope that long periods of spotlessness will not occur during the years which lie between the past maximum and the next one.

W. Gleissberg.

University Observatory, Bayazit, Istanbul, Turkey, April 15, 1948.

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